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THE FOURTH DIMENSION IN BUILDING: STRATEGIES FOR MINIMIZING OBSOLESCENCE

COMMITTEE ON FACILITY DESIGN TO MINIMIZE PREMATURE OBSOLESCENCE
Building Research Board
Commission on Engineering and Technical Systems
National Research Council

Donald G. Iselin
Andrew C. Lerner
Editors

Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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The term "obsolescence" calls to mind automobiles and washing machines, record players and watches—a range of consumer products that we discard, typically long before they have broken or worn out, simply because newer, more advanced, and (presumedly) better replacements are available. In our buildings and other facilities constructed to stand safely for decades, obsolescence is more difficult to comprehend.

We and the committee whose work is presented here questioned at first whether the term has useful meaning in the context of facilities. Many professionals seemingly use the term whenever they judge that substantial action is needed to return a facility to fully useful service, and they do not distinguish among the factors giving rise to this need.

Yet, new facility users and their new demands; new materials, technology, and procedures of construction and operation; new air pollutants; and new laws and regulations exemplify changes that lead us to alter design methods and our expectations of acceptable service long before older facilities are abandoned. Similarly, changes in organizations, variations in urban real estate markets, and the opportunities presented by new equipment and materials often lead us to renovate long before facilities and their parts are worn out. That we can accommodate change and yet retain at least some portion of the investment of capital, history, and culture embodied in our facilities is a great benefit. That we must do so, often at substantial cost, is a problem, particularly in times of fiscal stringency.

The ancient Roman designer Vitruvius advised that architecture should be possessed with "Firmness, Commodity and Delight," that is, well constructed, responsive to the functions the owners intend, and pleasing to the eye. This remains sage counsel today. However, although many of the edifices of ancient Rome continue to evoke wonder, few of them serve their original function. Successful buildings and other facilities operate not only in the three spatial dimensions; the fourth dimension—time—is crucial as well.

Philosophers may argue that firmness, commodity, and delight are constants in a changing world. We hope that our work will assist those who seek such

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This study was supported as part of the technical program of the Federal Construction Council (FCC). The FCC is a continuing activity of the Building Research Board (BRB), which is a unit of the Commission on Engineering and Technical Systems of the National Research Council. The purpose of the FCC is to promote cooperation among federal construction agencies and between such agencies and other elements of the building community in addressing technical issues of mutual concern. The FCC program is supported by 16 federal agencies: the Department of the Air Force, the Department of the Army (2 agencies), the Department of Commerce, the Department of Energy, the Department of the Interior, the Department of the Navy, the Department of State, the General Services Administration, the National Aeronautics and Space Administration, the National Endowment for the Arts, the National Science Foundation, the U.S. Postal Service, the U.S. Public Health Service, the Smithsonian Institution, and the Department of Veterans Affairs.

The Public Facilities Council (PFC) was formed in 1983 to make available to state and local governments, quasi governmental authorities, and others, the forum and services of the BRB and NRC to identify technical problems and research needs facing construction administrators and facilities managers. Sponsors of the PFC currently include a score of state and local governments or interstate entities. Funding and participation are typically drawn from the executive office of the jurisdiction responsible for facilities development and management.

Reports resulting from BRB programs are provided free of charge to sponsoring entities.

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CONTENTS

APPENDIXES

List of Figures

List of Tables

THE FOURTH DIMENSION IN BUILDING: STRATEGIES FOR MINIMIZING OBSOLESCENCE

EXECUTIVE SUMMARY

Public facilities are valuable assets that can provide decades of high-quality service if they are utilized effectively. Facilities are planned, designed, constructed, operated, and maintained to this end. Nevertheless, a time comes—perhaps through normal wear, poor workmanship, or overloads—when major action is needed to overhaul, renovate, or sometimes demolish a facility no longer providing satisfactory service.

Sometimes the motivation for such action comes primarily from outside sources. Users or owners may change and have requirements different from those the facility was initially intended to fulfill. Many of the technologies of modern facilities, as well as the activities they shelter and support, have changed substantially in recent decades and are continuing to change. These changes lead to rising expectations about the services and amenities a facility should provide. Rising expectations can effectively shorten the lifetime of a facility and are the essential characteristics of obsolescence. Accommodating rising expectations often has been costly, but failing to accommodate change is costly as well, for obsolete facilities—antiquated, old fashioned, and out of date—can impose heavy burdens on their owners and users.

These burdens may include lost productivity of people and activities housed and served by the facility, increased operating costs to overcome the mismatch of needs and facility capability, or increased worker absenteeism and health care costs related to on-the-job stress. The impact of obsolescence is sometimes subtle but often represents very real costs for the facility's owner and user.

Minimize the costs of obsolescence is one aspect of the complex task facing facility professionals working to assure effective acquisition and utilization of public facilities. The 16 federal government agencies that sponsor the Federal

spaces within the building are expected to serve (i.e., functional); the cost of continuing to use an existing building, subsystem, or component in comparison with the expense of substituting some alternative (economic); the efficiency and service offered by the existing installed technology compared with new and improved alternatives (technological); or the broad influence of changing social goals, political agendas, or changing lifestyles. Such changes often are embodied in the adoption of new standards or codes, rising expectations of performance, major technological change, major change in functional requirements, major organizational change, shifts in property values, poor maintenance or abuse of systems, or aesthetic shifts. These events and shifts spur obsolescence.

While these causes of obsolescence occur primarily as changes external to the operations of the facility in question, that facility's initial capabilities (e.g., durability of materials and flexibility of mechanical equipment) and how the facility is maintained influence the likelihood of obsolescence. Minimizing the impact of obsolescence—that is, minimizing its costs through actions in planning and programming; design; construction; operations, maintenance, and renewal; and retrofit or reuse (i.e., throughout the facility life cycle)—is accomplished by anticipating changes, accommodating changes, or both. Forecasting all change is impossible. However, facilities can be programmed, designed, and operated to be robust, to be able to accommodate change without substantial loss of performance capability. Experience shows that facility designers and owners can improve their ability to forestall or avoid obsolescence by taking the following actions:

- On a continuing basis, **review** new developments **for trends that may foster obsolescence.**
- Conduct facilities **programming to address** explicitly the possibilities of **future functional change.**
- **Assure that design guidelines and criteria are based on the latest available information and provide for future change** in technology and practice, **giving particular attention to facility types that are more susceptible to obsolescence** (especially, e.g., laboratories, hospitals, and others housing technologically advanced functions; schools; and correctional facilities).
- **Make flexibility an explicit design goal** and make appropriate use of design details or integrated building systems that enhance flexibility or

and utilities capacity that do not inhibit future expansion.

- **Assure that facilities fit users' needs and gather information for more effective accommodation to users' needs in future facilities.** Such tools as prototypical rooms (i.e., mock-ups) to test functional performance of interiors and utilities systems, commissioning, and postoccupancy evaluation may be helpful.
- Modify or **use alternative procurement methods to reduce the time between initial specification and in-service utilization** of facilities or components that may be "obsolete before complete."
- **Assure quality in construction and maintenance** to avoid deterioration of performance at rates faster than anticipated in design.
- **When obsolescence does occur, acknowledge it and retrofit or reuse** facilities to minimize the costs of obsolescence.

Delaying or minimizing the impact of obsolescence of public facilities sometimes presents special challenges because of the procedures and administrative framework within which government agencies must operate. Some of the actions already listed must be tailored to fit within this framework. Actions that serve particular needs of government policy and procedure are needed, such as the following:

- Assign specific, ongoing **responsibility to monitor trends that may hasten obsolescence.**
- **Link strategic planning explicitly to facilities requirements and, within a strategic planning framework, manage facilities as an asset** portfolio for which the costs, including the costs of obsolescence, are to be controlled.
- **Reduce the length of time required between facility design and effective occupancy** through appropriate use of such procurement methods as "government-furnished equipment" (i.e., direct and separate procurement, outside of the construction contract).
- **Budget procedures that permit stockpiling of parts and materials** that, if unavailable, could hasten obsolescence.

A first step toward more effective management is sensitivity both to the problems of change and the possibilities of accommodating change, which often means focusing on the details of individual facilities. **Government decision-makers should recognize that increasingly rapid change in both the**

1

INTRODUCTION

The lifetimes of buildings and other constructed facilities typically are long, but many of the technologies of modern facilities—as well as the activities they shelter and support—have changed substantially in recent decades. In many instances, accommodating these changes has been a costly process of alteration and reconstruction or outright replacement. At the same time, failing to accommodate the change is costly as well, for obsolete facilities—antiquated, old fashioned, and out of date—can impose heavy burdens on their owners and users.

Obsolete structures may be unable to accommodate new communication, building automation, or electrical systems. They may be inefficient in their use of energy. In some cases, obsolete facilities can pose safety hazards when they do not meet current standards of professional practice or building codes. These facilities may continue to be used, but their property value may decline as potential tenants and purchasers look to more modern facilities or demand lower rents. When users cannot move, the burdens of obsolescence eventually result in decreased efficiency, reduced output, and declining morale.

Government agencies and other long-term building owners seek to delay or avoid obsolescence and its costs. They find it increasingly important, especially in times of fiscal constraint, that their facilities contribute to efficient and effective pursuit of the agency's mission. At the same time, budgetary, technical, and administrative constraints often make it difficult to take action to correct problems of facility obsolescence.

obsolescence. The state and local government sponsors of the BRB's work, collectively known as the Public Facilities Council, agreed that the problems of facilities obsolescence warrant attention and participated with the FCC in this study.

OBSOLESCENCE AND OTHER SERVICE INADEQUACIES

Buildings and other facilities are planned and programmed, designed, constructed, operated, and maintained to provide shelter and service to meet the needs of owners and users. Over time the quality of service declines from its initial level as the facility exhibits the results of normal wear, poor workmanship or materials, unlikely events (e.g., severe storms or fire), aging, or some combination of such factors. Such decline generally is anticipated, but there comes a time when service is no longer adequate and substantial action is needed to overhaul, renovate, or demolish and replace the facility.

In common parlance a facility in such a condition might be termed "obsolete," regardless of the cause. However, the old saying "If it ain't broke, don't fix it!" highlights why it is important to distinguish between true obsolescence and other conditions requiring substantial action. Any facility or piece of equipment may function adequately in basic terms (i.e., "it ain't broke") but yet be so old, antiquated, or out of date (i.e., obsolete) that its service simply is unacceptable to its owners or users. The opposite case may hold as well: even the newest and most up-to-date item may break or otherwise fail to perform adequately, especially if not properly maintained. These relationships are seen most easily in the rapid evolution of microcomputers, where technological advances are driving many users to replace fully functional machines and software within 2 to 3 years of purchase, simply because newer models offer dramatically enhanced capability at relatively low cost (see box).

OBSOLETE ANTIQUES

No matter how well classic car buffs maintain their 1920s vintage Model T Fords, those

SCOPE OF THE STUDY

The study reported here concerns itself with the former condition mentioned above—with obsolescence. The central concerns of this study are how to distinguish what makes a facility or one of its components obsolete and what sorts of actions may be warranted in planning and programming, design, construction, operation, and maintenance to avoid or delay obsolescence. However, these topics are complicated because, as will be discussed especially in Chapter 2, faulty design, poor materials, or inappropriate maintenance practices may accelerate the onset of obsolescence.

The BRB formed a committee of professionals having the broad expertise and extensive experience needed to undertake this study.[1] The FCC agencies had posed their request initially as a problem of design but early in their deliberations the committee agreed that **obsolescence is not a matter of design alone but must be considered within the context of a facility's entire life cycle, from initial planning through operations and maintenance.** The committee's work—and this report—encompass the full range of facilities' service lives.

The BRB's committee examined the meaning of obsolescence, as applied to buildings and other constructed facilities; causes of obsolescence; factors that may make some facilities more prone to obsolescence; and effective strategies for accommodating change and avoiding or deferring obsolescence. The committee met several times during a period of about 1 year and heard testimony of federal agency representatives and experts in the private sector and academia.

The problem of obsolescence is hardly new, and the committee built on work of predecessors (see box). In 1951 the chairman of a BRB conference, Laboratory Design for Handling Radioactive Materials (BRB, 1952), opened the conference with these remarks:

> We should be concerned that in an age of rapidly changing technology our buildings are apt to be obsolete in terms of nuclear science before they are completed. For example...the blueprints for large new science buildings (being designed for two state universities)...had no provision whatever for the handling of nuclear

Some 30 years ago, the first "offices without walls" were proposed in Germany as a way of improving the flow of work, thus permitting rapid change for such firms as Buch und Ton (a mail-order firm in Gutersloth) and Krupp (at Essen). Except for stair and utility cores, these schemes were without solid partitions and used traditional office furniture arranged in functional groupings. Plants and low screens served to separate different areas. In the late 1960s Dupont and Kodak were among the first companies to test this type of plan in the United States. (Coupland, 1991; Pile, 1978.)

During the same time, a noted furniture company introduced ideas developed by researcher Robert Propst in a new line of office work surface, storage, panel, and seating units that could be combined in an almost endless number of configurations to simultaneously meet the changing needs of the organization and individual employees. Not long after, other manufacturers came out with their own interpretations of the work station and movable partition concept. However, worker response to such systems remains mixed.

answers but only new responses as these problems evolve and change. Just as the advent of incandescent electric lighting made obsolete the widespread use of gas for illumination in buildings, so newer energy-efficient technologies may completely supplant Edison's inventions in the buildings of the future. These changes in technology are not only inevitable; in the long term they are desirable because the new systems and services offer enhanced performance to the facilities, users and owners. However, in the short term, obsolescence can be costly. Thoughtful design and management can defer or avoid obsolescence and thereby improve efficiency as well as effectiveness of our facilities, and that is the ultimate aim of this study.

ORGANIZATION OF THE REPORT

The purpose of this report is to present the committee's considerations and recommendations on design and management to avoid obsolescence and its costs. Although the committee focused on government facilities, particularly at the federal level, obsolescence is a problem shared by both private and public sectors, and the committee's deliberations thus considered the full range of facilities. Therefore, this report may be helpful and have bearing on facilities design and management in both private and public sectors.

The chapters summarize the committee's discussions of obsolescence and

approaches for delaying its occurrence, ranging from specialized systems and design elements for particular building types (e.g., hospitals and laboratories) to retrofitting and changing a building's use. The committee reviewed such experience, considering particularly the context of federal agency requirements, to derive their recommendations.

- Chapter 4 presents a series of guidelines for actions that can be taken—during programming, planning, design, and during the service life—to deal with change and avoid obsolescence.

These guidelines can be applied to private as well as public facilities. Facilities owners and designers have specific roles in implementing guidelines for avoiding obsolescence. To be most effective, actions to avoid obsolescence must be initiated early in the design and procurement process and continued throughout the service life. Both designers and facilities managers, individually and in partnership, have roles to play.

The appendixes present a glossary of terms, bibliography, and discussions of selected topics that supplement and expand on particular aspects of the committee's work.

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2

OBSOLESCENCE IN FACILITIES

Obsolescence is the condition of being antiquated, old fashioned, outmoded, or out of date. The obsolete item is not necessarily broken, worn out, or otherwise dysfunctional, although these conditions may underscore the obsolescence. Rather, the item simply does not measure up to current needs or expectations (see box).

THE WORD ITSELF

Webster's Ninth New Collegiate Dictionary (1985) traces the word "obsolete,"—meaning "no longer in use," "old fashioned," "vestigial,"—to Latin roots in the sixteenth century. "Obsolescence," the "process of becoming obsolete or the condition of being nearly obsolete," appeared much later—in the mid-nineteenth century.

People tend to replace or discard tools, clothing, and other possessions that they view as obsolete. Possessions also may be discarded or replaced because they are broken or worn out, but this is not the same as obsolescence.

Preserved long enough in good condition—100 years is a commonly used criterion—an obsolete or "antiquated" object may be venerated as an "antique." The latter term is said to have entered the English language from French, at about the same period that "obsolete" came into use.

buildings have become obsolete because they cannot accommodate the increasing dependence of businesses on personal computers and an array of new communications equipment. In most cases things or concepts that are obsolete continue to function but at levels below contemporary standards.

IDENTIFYING OBSOLESCENCE[2]

As was described in Chapter 1, when reduced performance of a facility affects the activities of building occupants, the impact can result in lost efficiency, rising costs, reduced output, and declining morale. Even if the occupants are not affected directly, property values may decline as potential tenants and purchasers look to more modern facilities to meet their changing needs and increased expectations.

External changes that can cause obsolescence include introduction of new technology, neighborhood deterioration, or shifts in public demand for the services and amenities a facility provides. Such changed requirements or expectations regarding the shelter, comfort, profitability, or other dimensions of performance are typical, inevitable, and—in many observers' opinion—accelerating in pace.[3] Federal agencies, like other building owners, have found it necessary periodically to modify facilities in order to bring them up to date and to remedy features that no longer fulfill user needs. Often, these modifications are especially costly because the designs of older structures are not adapted easily to new systems, finishes, and interior layouts. In extreme cases of obsolescence, it has been more cost effective to demolish and replace structures rather than renovate them. For example, St. Louis's Pruitt Igoe low-income housing project was demolished because of the project's apparent exacerbating effect on the social problems it was meant to solve.

Sometimes problems arise because agency design guidelines are outdated or do not address new requirements, sometimes, when new materials or products are emerging rapidly, there is a general lack of information upon which to base facility decisions; and sometimes the slow pace of the federal budgeting process permits needs to shift while authorizations are sought to construct facilities for

which programming and design are complete already. All of these are causes of obsolescence.

The initial capabilities of a facility and how it is maintained, though not causing obsolescence directly, can influence the onset of obsolescence. For example, use of inflexible partitioning systems or failure to maintain mechanical systems can hasten the time when users or owners judge that a facility is no longer adequate for their needs, particularly if, at the same time, other facilities and mechanical systems offering better performance have become available .

The impact of obsolescence may be directly adverse, as is the case when changes in neighborhood character cause declines in rents or when new concerns for energy conservation lead owners to decide that a building's heating or cooling demands are excessive. Frequently, obsolescence may simply mean that new technology or design standards offer improved performance compared with the existing facility can deliver, and users are placed at a disadvantage compared to occupants of newer or modernized facilities.

Obsolescence may have consequences for the user's business. For example, the adoption of optical bar-code technology in motor vehicle freight management has led to longer trailers, necessitating longer loading bays for U.S. Postal Service facilities. Older post offices—that is, those with short bays and low roofs—are seriously obsolete regarding this changed technology. Similarly, the advent of multimedia office automation systems (i.e., integrating sound, video, and still imaging with data storage and access) could revolutionize office design and use by replacing conventional voice and data communication.

Apart from the major monuments that survive, sometimes for centuries, with function unaltered, most facilities, to some degree, become obsolete before their structures basically unsafe or otherwise unfit for use. However, obsolescence becomes a significant design and management issue when it occurs prior to the end of the *design service life*: the length of time for which a building, subsystem, or component is designed to provide at least an acceptable minimum level of shelter or service, as defined by the owner.[4]

For many types of buildings, and for purposes of financial analysis, this design service life typically is assumed to be 15 to 30 years. Interior finishes and technology subsystems generally are expected to have much shorter service lives, whereas structural frames, foundations, and exteriors are recognized to be longer lived. These expectations of design service life provide the basis for

deterioration has rendered it useless" (Kirby and Grgas, 1975). Sometimes failures caused by design or fabrication errors bring an early end to the physical life. However, more typically, over the years roofs need replacing, mechanical equipment breaks down, metals corrode, and sealants erode, regardless of users' needs, economic factors, or technological advances. These conditions are not obsolescence, although the repairs or replacements may incorporate materials or parts that use new technology and thereby defer or redress obsolescence.

For example, the physical life of the basic structure and many of the interiors of the U.S. Capitol building are approaching 200 years and are likely to continue for additional decades. Nevertheless, obsolescence over the years has led to many changes in electrical and mechanical systems and to construction of several new buildings to provide offices and meeting rooms when the original plan became inadequate. In contrast, the Washington, D.C. old central post office, constructed on Pennsylvania Avenue at the end of the nineteenth century, was by the 1960s essentially obsolete and abandoned by the U.S. Postal Service in favor of newer and more functional facilities. However, the facades and structure were preserved when adaptive reuse in the 1970s converted the building to offices, a shopping mall, and a tourist attraction[5] (Craig et al., 1984).

Whatever the cause, any element that has reached the end of its physical life has, in fact, failed and must be replaced, repaired, refitted, or abandoned. An element that has reached the end of its service life, on the other hand, can continue to function (albeit at less-than-adequate performance) and may or may not be replaced or refitted. Obsolescence can end the actual service life sometimes years before the designers anticipated that the end would occur (see box).

The many separate systems that compare a building (e.g., lighting, HVAC [heating, ventilation, and air conditioning], roofing, and cladding) must each perform well for the building's overall performance to be adequate. If any one system fails or becomes obsolete, the entire building may be judged unacceptable.

PROGRESSION OF THE SERVICE LIFE

Figure 1 illustrates conceptually the progression of a facility's performance during its service life (i.e., following completion of construction).

OBSOLESCENCE ILLUSTRATED

An enterprise (government agency or private corporation) has decided to use the ground floor of a downtown building as a customer service area and, as part of its plans for the space, intends to locate a small gallery there for rotating exhibits. The exhibition area may attract some visitors, but the enterprise expects most viewers to be people who have other business with the customer service staff. The interior designer suggests using a custom carpet, featuring the organization's colors and logo, as a strong and unified public image for the space. The specifications for the carpet are developed based on standard materials available and projected use over the next 5 years.

CASE 1: Visitor traffic is close to what was forecast, but the carpet wears badly. The problem is found to be a cleaning agent, used for a short period by a maintenance contractor, that reacts with the fiber in the pile. After 3 years the carpet must be replaced.

CASE 2: Visitor traffic far exceeds expectations. The carpet wears well in comparison with traffic but nevertheless is badly worn after 3 years, at which time the enterprise decides to replace it.

Cases 1 and 2 are concerned with physical life and failure, caused by maintenance errors or unanticipated usage, rather than obsolescence.

CASE 3: The enterprise undertakes strategic planning and a reorganization that result in substantial changes in corporate image. As part of this process, a decision is made to discontinue the exhibitions and convert the ground floor area to offices. The custom carpet, still in good condition, is removed and junked after only 3 years.

CASE 4: New medical evidence identifies chemicals used in fiber manufacturing as serious allergens, and the EPA issues regulations effectively banning the use of these chemicals in applications that bring them in contact with people. The enterprise is notified by the manufacturer that its custom carpet incorporates these chemicals but that the regulation exempts materials in place. Noting that there have been no complaints during the 3 years since the carpet was installed, the enterprise decides that no immediate action is warranted.

Cases 3 and 4 are examples of obsolescence caused by changes in functional requirements or regulatory (i.e., social and political) factors.

"Performance," meaning the facility's ability to provide the shelter and service

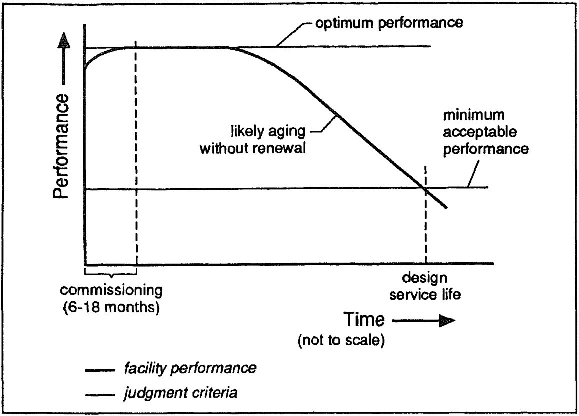

Figure 1 A conceptual view of service life.

factors. The complexity of building systems defies definition of any single parameter adequate to measure all aspects of performance. Hence, to judge performance or obsolescence effectively, one must consider each functional system or subsystem.

As shown in Figure 1, performance at initial occupancy—the facility's initial capability—is typically less than the design ideal. Generally, a modest "shakedown" or "shakeout" period of time necessary for the building, subsystem, or component—and its operating personnel—to reach this anticipated optimum level of performance. Careful commissioning of new facilities can help to assure that much of this shakeout is accomplished prior to occupancy. Problems unresolved in the shakedown period or a design that fits poorly with the user's needs will be reflected in a peak performance level below an optimum

performance deterioration to reach minimum acceptable levels. Efforts to make precise predictions of the length of service life, physical life, and the course of performance with time—for major building components, subsystems, and entire buildings—have been the subject of study for several decades, and progress has been slow (refer to Appendix D). Experience, custom, and rules of thumb continue to be the primary sources of estimates for these parameters. Design decisions and owners' investment decisions typically are based on an assumption that adequate performance can be delivered for 15 to 30 years (a design service life, as previously defined). Rarely, however, does this period elapse without some periodic renewal or refurbishment—replacement carpets, painting, and overhauling of compressors, for example—that increase performance during the service period and effectively extend the service life (see Table 1).[6]

A variety of regulatory requirements and design practices influence actual service lives; also, in the private sector, tax laws and the lending practices of financial institutions may have as much or more to do with determining this time period than does engineering information. For example, safe and stable building structures typically survive beyond the time periods over which their accounting values are depreciated to zero. In practice, actually, most buildings provide adequate service over periods considerably longer than those explicitly considered in design, and the physical life for a building as a whole normally can be expected to extend beyond the design service life—to 20 to 40 years or more. As Table 1 illustrates, anticipated service lives vary substantially among building types and building subsystems.

If maintenance is neglected or conditions of use are more demanding than anticipated during design, performance deterioration may proceed more rapidly than expected. As Figure 2 illustrates, this deterioration is indicated by a more steeply declining performance curve, and the minimum acceptable performance is reached sooner. Thus, the service life is reduced. Such a reduction in service life—below design levels—is typically is judged a failure by users or owners, although sometimes a maintenance effort above "normal" levels can extend the service life beyond its design target.[7]

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[6]These service-life estimates may be understated. Experience in the United States is that properly maintained centrifugal chillers, for example, will last 18

COMPONENTS	FACILITIES					
	Public Housing	Condo-miniums	Retail	Hotels	Office	Air-ports
Upper floors	10[a]	—	—	—	—	—
Roof						
Construction	20[b]	—	—	—	—	—
Coverings	10	10	7	10	10	5
Stairs	5[a]	20[b]	—	—	10	10
External						
Walls	5[a]	25[b]	5	10–15	15	5
Parting	5[a]	10[a]	5	10–15	15	4
Windows	10	15[b]	10	—	—	10
Doors						
External	5	25[b]	7	7–10	10	10
Internal	—	10	10	6	—	10
Games court resurfacing	—	2–3	—	—	—	—
Ironmongery	—	20[b]	7	6	8	5
Wall finish	5	—	7	4	5	5
Floor finish	5	10	7	6	12	2
Ceiling finish	—	25[b]	7	—	6	5
Decoration						
External	5	3–5	5	5	3–5	1
Internal	5	1–2	5	6	10	1
Sanitary fittings	—	5	7	20	10	5
Water/sanitation	—	10	5	3	10	10
Air-conditioning						
Cooling tower	—	10	10	10	10	—
Chiller	—	10	10	10	10	—
Ducts	—	10	10	10	10	—
Electrical						
Wiring	20[a]	10–15[b]	10	20	12	—
Fittings	20[b]	10–15[b]	10	6	6	—
Drainage	15[b]	10–15[b]	7	20	15	—
External works	10	3–5	10	10	15	—

[a] Minor replacements.

[b] Estimated figures.

Source: Fong, 1990

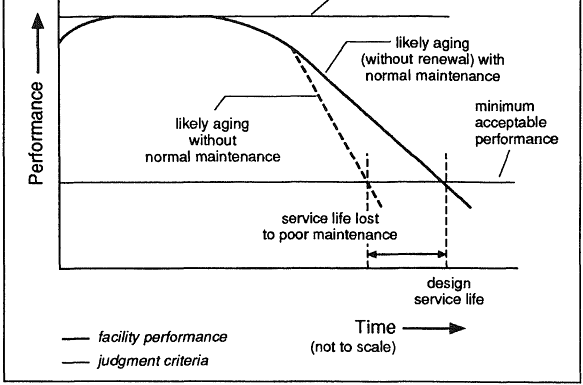


Figure 2 Maintenance practices can influence service life.

RISING EXPECTATIONS AND THE ONSET OF OBSOLESCENCE

For the sake of simplicity, Figures 1 and 2 portray as unchanging the levels of performance judged to be optimum or the minimum acceptable as unchanging over the period of the facility's service life. This is seldom the case in practice, except perhaps regarding a few basic aspects of performance, such as structural stability and shelter from inclement weather. More typically, users' and owners' expectations change over time as a result of the development of newer facilities, the introduction of new products, and increased experience (see Figure 3).

For example, new lighting technology and product designs coming on the market may offer lower energy consumption and make the existing lighting fixtures seem old fashioned. People also may come to expect faster elevators, installed data transmission systems, electronic security systems, and personalized zoned heating and cooling controls. Figure 3 portrays the rising expectations

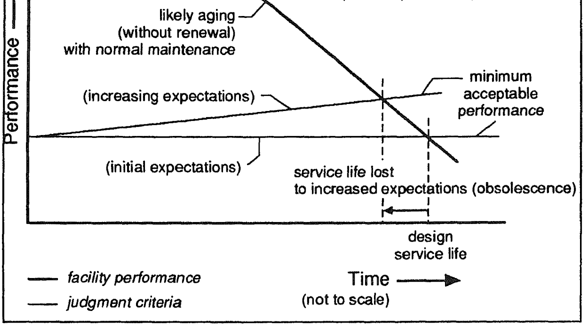


Figure 3 Standards or expectations of performance may change with time.

Shortening of the service life because of rising expectations is the essential characteristic of obsolescence. As was already, obsolete systems frequently are replaced even though they are performing at levels that were considered adequate at the time of design. If they are not replaced or refurbished, they impose a variety of other costs on the building's users and owners. These costs spring primarily from losses in productivity of the people who use the facility. Staff forced to work under awkward or unhealthful conditions perform less effectively than their competitors and feel stress. Output is restricted or diminished, and absenteeism and health care costs may rise.

A number of factors, falling roughly into four broad categories, may cause rising expectations, obsolescence, and increased expenses:

1. **Functional factors**, that is, those related to the uses a building or spaces within the building are expected to serve (e.g., when the building's occupants change);

2. **Economic factors**, referring primarily to the cost of continuing to use an existing building, subsystem, or component compared with the expense of substituting some alternative (e.g., when a building cannot compete effectively with its newer neighbors for tenants and rents);

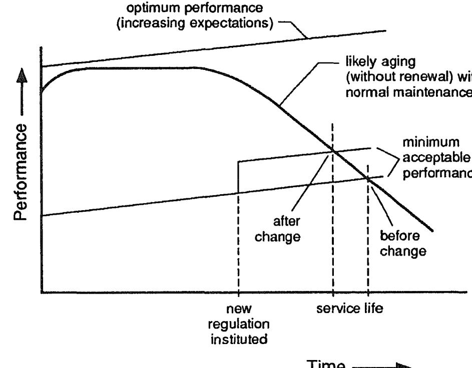
3. **Technological factors**, referring to the efficiency and service offered by

(e.g, when electrical power distribution and grounding systems are no longer able to accommodate the demands of current office automation); and

4. **Social, legal, political, or cultural factors**, that is the broad influence of social goals, political agendas, or changing lifestyles (e.g., when a building fails to meet the requirements set in new legislation for accessibility by people with physical disabilities).

In fact, when owners or users judge their facilities (or some components of their facilities) to be obsolete, they often arrive at the conclusion because of the complex interaction of many such factors.

Factors in the fourth category, and particularly promulgation of new regulations or standards, are particularly important because they can cause a sharp rise in performance requirements within a short period of time. Figure 4 illustrates the effect. The Americans with Disabilities Act, for example, is forcing many building owners to make physical changes in their otherwise satisfactory facilities to enhance accessibility by handicapped persons. Similarly, the removal of asbestos from many school buildings is a response to public health concerns, even though the response may not be required by law. Appendix C discusses further the effect of regulatory factors in fostering obsolescence.



accommodate new functions are among the activities that building owners and users undertake periodically to improve the facility's overall performance. Figure 5 illustrates how these periodic renewals raise performance level and extend service life.[8]

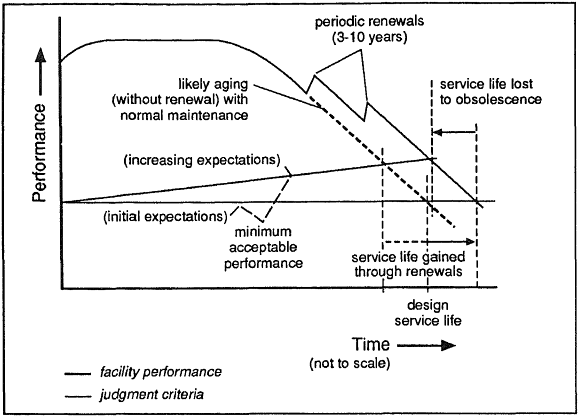


Figure 5 Periodic renewals raise performance and can extend service life.

SCALE OF THE OBSOLESCENCE PROBLEM

Obsolescence becomes a significant problem when it occurs in the early years of a facility's service life. Although the committee could find no comprehensive basis for estimating the scale of facilities obsolescence problems, anecdotal evidence suggests that the problem is substantial. With frustrating

consolidations, and growth in the information-based sectors of the U.S. economy of the 1970s and 1980s have forced much of the functional obsolescence. Committee members familiar with both commercial real estate management and government facilities utilization note that 3 to 5 year intervals now are typical for virtually complete changes in office-space utilization. As a result, many large institutions are choosing modular partition and furniture systems for their major facilities in order to make it easier to reorganize space to fit the reorganized company or agency. Other institutions have invested additional funds as part of the design and construction of new facilities in order to make provisions for later expansion and changes in patterns of use (see box).

SAVING MONEY BY DELAYING OBSOLESCENCE

One traditional approach to avoiding obsolescence is to build excess unfinished space in new structures. Finishing is completed when the space is needed for current activities. At Iowa State University the Pearson building was constructed in 1962, with no provision for a basement. A basement was added in 1980. The Agronomy Addition, constructed in 1984, included an unfinished basement shell that was then finished 2 years later. The cost to construct space under the Pearson building was estimated to be about 20 percent more than if it had been built along with the rest of the building. This 20 percent premium was a cost of obsolescence.

The initial investment required to construct an unfinished shell below grade, based on the Agronomy Addition experience, would have been approximately 25 percent of normal fully finished costs for the basement. That is to say, an additional investment made at initial construction of one-quarter of the cost for a fully finished basement would have made the overall construction easier (i.e., constructing the shell space and later finishing it, versus construction of new space under a finished building) and avoided the 20 percent premium.

In retrospect, the savings the university might have achieved from constructing "shell space" under the Pearson building, in anticipation of a need as much as 18 years later, would have yielded a greater than 8 percent annual rate of return on the investment (allowing for increases in construction costs). Avoiding disruption of ongoing operations and earlier use of the space are additional savings that such action yields. The construction of "shell space" is one strategy for delaying or avoiding obsolescence.

Source: Information provided by the Iowa State University Office of Facilities Planning and Management.

property values, high inflation, and high interest rates in the past two decades have shortened substantially the time horizon for facility investment decisions, forcing more rapid economic obsolescence of older facilities. The trend has been most notable in some residential markets, where "tear-downs"—demolition of sound older houses in order to permit new construction on the property—has become commonplace.

The severely depressed real estate market of 1991 supported the contention of some professionals (e.g., Pilzer, 1989) that there has been too much new construction at a time when rates of business expansion have declined. In addition, for users of retail space, brand-focused, higher-efficiency (as measured in dollar sales per square foot) mass merchandisers are becoming predominant, reducing the overall demand for retail commercial space. These trends, coupled with the impact of computer-based mail and telephone ordering, just-in-time delivery, and, consequently, reduced inventories, point to a continuing decline in the need for retail space and warehouses. Similar downsizing is occurring in many manufacturing businesses, and the move to smaller offices and to the "telecommuting" that permits information workers based at their homes to be linked by telecommunications into a productive corporate network may lead to similar results in the office sector. Taken together, these trends suggest that many new facilities have become obsolete.

The energy crisis of the 1970s and subsequent lesser fuel-price shocks have stimulated development of energy-saving technologies for HVAC equipment (e.g., direct digital controls, variable air-volume devices, and electronic sensors and software for controlling system balance), new insulation materials, and energy-conserving facade and roof designs (Kelsey and Webb, 1990; Sequerth and DeFranks, 1987). Such developments have rendered many older HVAC systems—and sometimes entire buildings—obsolete.

Rapid change in telecommunications and in computer technologies has had a similar effect on buildings, giving rise to the new professional activity of "wire management." Buildings lacking such elements as raised floors, easily relocatable data-grade cables, and switches to accommodate local area computer networks and private telephone systems are viewed by many users as obsolete (*Building*, 1985; *Building Design and Construction*, 1986; Building Research Board, 1988; Doyle 1985; Sraeel, 1988.) In the future, further advances in flat-wire and wireless technologies may reduce or eliminate the need for these raised floors and cables, thereby rendering yet other facilities obsolete.

typical functional life span of chemistry laboratories to about 7 years. In hospitals, same-day surgeries—comprising only about 15 percent of cases a decade ago but currently over 60 percent in many facilities—have drastically altered patterns of space use and the demand for surgery and supporting laboratory facilities. Such new diagnostic and treatment technologies as positron emission tomography (PET) have brought to the hospital new large and heavy equipment that cannot be moved or housed easily in older buildings. Such highly specialized activities as intensive coronary care, trauma treatment, and neonatal medicine require uniquely equipped operating rooms that were not foreseen when older, and now obsolete, health care facilities were designed.

The Americans with Disabilities Act of 1990, now coming into full force, is the most recent example of social and political causes of obsolescence. Characterized as a civil rights law (Raeber, 1991), the ADA requires that new and remodeled buildings be fully accessible and safe for people with disabilities, and it introduces a new set of agencies (the Justice Department and the Equal Employment Opportunity Commission, new to facilities regulation) to issue guidelines and enforce requirements. The result of this social and political source of obsolescence may be to make many buildings that might otherwise be remodeled to accommodate functional or technical change too costly to update. Similar costs may result from imposition of the Uniform Federal Accessibility Standards, applicable in lieu of ADA for federal and federally funded facilities.

A workshop sponsored by the committee (Appendix C) examined other such causes of obsolescence and identified a wide range of environmental and occupational health concerns, now emerging, that could become important in the next 3 to 5 years. These concerns are summarized in Table 2.

INCENTIVES TO AVOID OBSOLESCENCE

The costs of obsolete facilities are incurred when the effort is made to update the facility or when the user and owner lose operating efficiency owing to facility performance. It is these costs—imposed directly on the owners and managers of facilities, indirectly on users, or on both—that are the primary incentive to avoid obsolescence. Effective delay or avoidance of obsolescence can reduce the overall costs of facility ownership.

Avoiding obsolescence means following several courses of action: (1) planning and designing to avoid obsolescence and to provide the flexibility to

'able 2 Potential Future Issues of Environment and Health That Could Influence Building Obsolescence
ıonresidential)

Nature of Problem	Examples or Details	Implications for Building Obsolescence
Refrigerants in HVAC equipment	• Chlorofluorocarbons (CFC) banned in new applications and production and to be phased out because of damage to ozone layer • Potential substitute, HCFC-123 (halogenated CFC), now shows toxicity	Manufacturers are searching for alternatives. Buil industry may have to develop systems that can acc wide variety of materials. Energy efficiency may Installation workers could be exposed to chemical
Exposure of construction workers to hazardous materials	• Asbestos • Sprayed insulation • Mercury (in paint) • Lead • Formaldehyde • Tetrachloroethylene • Methylene chloride • Fibrous glass, manmade mineral fibers	Occupational Safety and Health Administration (OS regulations require notification of workers regardi risks. Problems will arise as new materials are fo hazardous.
Indoor radon	Problem tends to be more acute in some geographic areas. Associated with ground contact and therefore anticipated to be less of a problem in nonresidential buildings.	EPA ranks this problem high, but the public has n responsive. Good ventilation (i.e., positive pressu reduces risk, but manufacturers may hesitate to int some products that could influence liability exposu
Indoor chemical air pollutants (other than radon) and toxic materials	• Residual solvents (associated with paints, fabrics, carpets, and adhesives) • Synthetic polymers • Biocides (mercury in paint, pest-control materials)	Increased measurement capability may implicate a increasingly large number of materials. Monitorin conditions may become standard, requiring retrofit older facilities.

nd pathogens	filters and duct linings • Wall and floor surfaces and coverings	
ire toxicity	• Polymeric materials (wiring, finishes, insulation, pipe, conduit)	Increased toxicity testing may implicate an increasin number of materials. Retrofitting could be required renovations or alterations are made.
/aste reduction, aterials cycle, and sposal of hazardous nd toxic chemical nd biological wastes	• Demolition and waste recycling • Paints, mastics, and sealers waste disposal • Cleaners and solvents	More stringent restrictions on landfills and pressures recycling could alter construction processes and enha attractiveness of some materials over others (e.g., st frame rather than concrete, for recycle potential). S storage and compaction or other processing of mater recycling will be required. Special fire protection ar safety provisions may be needed.
ltraviolet and visible pectrum light	• Control of light-intensity influencing glare and worker performance • Screening of ultraviolet radiation, for cancer risk	Photosensitive or other specially tinted glass, or scre materials, could be required in facilities housing wor
lectromagnetic diation	• Video display terminals • Electrical cables and controls • Radio frequency controls and signals	Shielding could become necessary, and development noncabled applications could be influenced.
/ater shortages and onservation	• Sinks, toilets, other plumbing fixtures • Plumbing for greywater recycling • On-site primary treatment	Water-saving fixtures may become more important i areas, and recycling requirements could lead to incre retrofitting requirements.
lobal warming, reenhouse effect	• Direct emissions of CO_2 • Energy consumption for indirect CO_2 emissions reduction	Verification of the problem could require retrofitting gas/oil- burning boilers and furnaces, incandescent li and underinsulated buildings.

Source: BRB staff and workshop participants (refer also to listed references).

thereby deferring obsolescence, and (4) refurbishment and retrofitting to accommodate change. The losses through failure to manage effectively are measured in early occurrence of unsatisfactory performance, a reduction in service life, and costly obsolescence.

Many ways have been found to avoid obsolescence in the two decades since a speaker at a 1971 BRB symposium observed that routine renovation and rehabilitation, had for the past 50 years, been the most effective approach to taking advantage of most of the "architectural and mechanical changes occurring due to new technology" (Cherry, 1972). That speaker's experience in the early 1970s was that such items as column grids over 30 feet and underfloor wiring ducts in concrete structures, when evaluated on a discounted cash-flow basis, generally did not warrant the additional expense (although designing to provide up to 100 pounds per square foot of additional floor load-bearing capacity did give tenants and owners useful options for rearranging functions). Two decades later the conclusions have changed. The construction-related industries have found ways to reduce the costs and add flexibility, and others may yet be developed. Chapter 3 presents the committee's assessment of the experience and prospects for avoiding obsolescence and its costs.

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3

ACTIONS AND STRATEGIES FOR AVOIDING OBSOLESCENCE

Avoiding obsolescence or minimizing its costs can be accomplished through actions in planning and programming; design; construction; operations, maintenance, and renewal; and retrofiting or reuse of a facility (throughout the facility life cycle). These actions generally have the purpose (or, perhaps, inadvertent effect) of (1) minimizing the impacts of obsolescence by anticipating change or (2) accommodating changes that cause obsolescence before the costs of obsolescence become substantial. These costs, in turn, may occur at various times during a facility's life cycle and must be viewed within this total life-cycle context. The committee drew on a variety of noteworthy cases, as well as on the members' broad experience, to illustrate the range of such actions and potentially useful strategies for avoiding obsolescence or minimizing its costs, as described in the following pages (see box).

ACTIONS IN PLANNING AND PROGRAMMING

It is impossible to foresee accurately all changes that will occur over the decades-long service life of a facility. Nevertheless, thoughtful planning and programming of a facility can do much to avoid early obsolescence, both for

The committee identified a wide variety of specific and detailed actions that can be taken at all stages of a facility's development and use to avoid obsolescence and its costs. Many of these actions fall within a few broad strategy-categories that can be pursued, particularly in design, to achieve these ends.

Actions in Planning and Programming

- Scanning for trends that may foster obsolescence
- Programming for the possibilities of future functional change
- Preparing for design through predesign analysis

Actions in Design

- Assuring currency of design guidance
- Targeting obsolescence—susceptible building Types
- Using integrated building systems
- Making flexibility a design goal
- Adopting details that enhance flexibility
- Unconstrained interior space
- Accessible service areas
- Modularity
- Shell space
- Using prototypes to test performance
- Sizing components to serve demand growth

Actions in Construction

- Separating procurement of sensitive components
- Commissioning

Actions in Operations and Maintenance

- Using postoccupancy evaluation in facility management
- Adapting for reuse
- Managing the facilities portfolio
- Making do

Action also may be taken in reuse and retrofit, which give a new service life to a facility and thus are similar to new design, but whose costs may sometimes meet or exceed those of new construction. Historic or other design value or very difficult construction conditions often justify these high costs.

Many of the technological and sociopolitical changes that may lead to building obsolescence evolve over periods of several years. New medical technology, for example, typically is "on the drawing boards" some 10 to 15 years before its widespread adoption in hospitals. Similarly, current behavioral research that is now yielding a better understanding of how people find their way to exits in building fires will become the basis for future building code requirements. Also, new environmental and health regulations emerge from a legislative process that generally takes 3 to 5 years, and scientific and engineering publications, and even major newspapers, often report on developing trends that may have an impact on facilities performance requirements. For example, one participant at a BRB workshop suggested that the newest discoveries in analytical chemistry, in particular, may be a powerful predictor of the environmental or health concerns that will emerge within 3 to 5 years, for these discoveries advance our ability to detect new health problems and the environmental substances that may cause them (refer to Appendix C).

Facility owners and designers can "scan" or "screen" published literature and other current information sources (e.g., computerized information systems and professional meetings) in order to spot emerging issues; indeed, the owners of large inventories of facilities (such as government agencies) have a substantial incentive to make this effort. Generally speaking, an essential element of professional responsibility for architects, engineers, and other building professionals is to keep abreast of new developments in their fields. Professionals who fail to do so can become obsolete themselves. However, the rate of change and growth of information in the building-related professions is such that individuals must work together in this effort.

For example, the U.S. Environmental Protection Agency (EPA) staff currently is active, in professional forums and through informal professional networks, in alerting designers to emerging environmental problems and the likely governmental responses to them. Plans for establishing a more formal clearinghouse operation reportedly have been made. Such professional and trade groups as the American Institute of Architects (AIA) and the Electric Power Research Institute (EPRI) are active as well. The AIA has an environment committee formed to develop a resource guide, that focuses on the environmental implications of various building materials for architects. The EPRI is working with the EPA to alert energy engineers to utilities management

Programming for the Possibilities of Future Functional Change

Recognizing that change is inevitable, the people who prepare a facility's functional program should view the specifics of use dictated by the building owner and its initial users as simply the first of many uses for which the building should be planned—what some designers term the "opening configuration."[10] The facility owner and user can draw on their corporate memory of past organizational evolution to reflect on functional changes that may occur in the future. Programming and design professionals working with the owner then can prepare alternative program *scenarios that reflect* possibilities for the future. The most probable scenario is used as the primary basis for design, but the design can be tested for its ability to accommodate other scenarios, and modifications in the design might be made accordingly in to enhance the facility's ability to accommodate alternate scenarios. Scenario analysis should include consideration of when a change of user may occur, the degree to which the facility fits well with the short- and long-term needs of the assumed new users (i.e., subsequent to the user for whom the opening configuration is defined), and the consequences of poor "fit." Subsequent analysis of life-cycle costs of design alternatives is based on these scenario characteristics.

Corporate strategic planning is a key source of information about new users and about other possible future changes a facility may be called on to accommodate. The U.S. Postal Service, for example, working to develop a better strategic understanding of the relationships among its administrative organization, functional requirements (e.g., mail handling and distribution, as well as sales), and building stock, has been developing concepts of what the postal "store of the future" should be. Competition (from such services as Federal Express) as well as changes in mechanical equipment are factors considered in this strategic planning, which could lead to changes in market characteristics, product mix, and consequent facility obsolescence.

For designers and for owners of a substantial building inventory, postoccupancy evaluation (POE) is a valuable aid in programming. The POE yields an assessment of how well a facility's performance matches the design optima and users' needs. That assessment, typically made at the peak of performance (i.e., after the building's shakedown period), provides information useful in both management of the current facility and design of new ones in the future. Accumulated experience on (to adopt the term from statistics) "goodness

present and future users.

The U.S Postal Service, for example, has adopted a POE system, used internally by the staff, that has established an effective feedback of information from operating experience into subsequent planning and design activities. The POE system collects information on customers as well as employees, and it includes criteria on function, aesthetics and image, cost, and technical performance (giving rise to the "FACT" acronym of the system's name).

The Naval Facilities Engineering Command (NAVFAC) distributes a concise POE evaluation form—the Design Feedback Form—to personnel occupying new facilities constructed under NAVFAC's control. The form asks various constituents (e.g., user, sponsor, maintainer, and visitor) to rate a long list of the facility's characteristics, including size, layout, and lighting; HVAC; elevators; communication and electrical systems; and others. Information gathered through the survey, which also includes more general questions regarding suitability to mission, best and worst features, and potential money-saving modifications, is used in subsequent operations as well as in future design.

Preparing for Design Through Predesign Analysis

Scanning and programming are preludes to facility design, and the consideration of future change should proceed smoothly from these prelude activities into design. Architect Richard Rodgers,[11] for example, has made accommodation of change a basic element of his design philosophy (Caplan, 1988):

> I believe that many architects misjudge the private needs of buildings. The rate of change in society—and you can pick the computer or whatever you want as a symbol—makes long term prediction impossible and inflexible building unreasonable. A set of offices today may be an art gallery tomorrow. A perfume factory may switch to making electronics. What we can do—and this is the key to much of my work—is to design buildings that allow for change, so they can extend their useful lives....

Rodgers does this by separating the services from a building's usable space,

have to close when the services are being renewed. (Rodgers' designs have yielded other economic benefits as well. Placing the services on the exterior of a building increases the proportion of usable space inside: to about 85 percent in his 1991 Lloyd's building in London as compared with 48 percent in the 1958 building his new design replaced.)

One increasingly practical way to put such a philosophy into practice is by predesign analysis of major design options. Computer-aided design (CAD) software is reducing the costs and time required for developing conceptual design alternatives and for working out a variety of design details before the actual detailed design begins. The multiple-building owner with a substantial volume of repetitive building nevertheless will still derive a greater benefit from the investment in predesign effort compared to the owner of a single unique building.

The Veterans Administration (VA), for example, has found its integrated hospital building system (VAHBS; see Appendix E) to be an effective tool for managing facility obsolescence and attributes the system's success, in part, to a substantial investment in predesign analysis of the VA's recurring needs and problems. According to VA estimates, from experience with more than 10 new VA hospitals built with the integrated building system and another 10 built in the private sector, VAHBS benefits are measured in remodeling costs that are only 70 percent of those for conventional designs. (In addition, faster construction and better performance have been achieved as well, purportedly with little or no increase in bid cost.) The Army has a somewhat similar system, developed under the acronym IBS (integrated building systems; also described in Appendix E). These integrated systems have provided space that is very flexible and easy to maintain—valuable attributes for such facilities as hospitals and research laboratories.

ACTIONS IN DESIGN

The design stage of facility development is crucial in avoiding obsolescence in that it determines not only the spatial relationships of activities the facility serves but also the interactions among functional subsystems (e.g., electrical, telecommunications, and HVAC), each of which may be influenced by obsolescence in any of the others. And just as these subsystems are related, so too is design to avoid obsolescence tied closely to activities in construction and

Assuring Currency of Design Guidance

Current design guidelines and building codes are prerequisite's of effective design to avoid obsolescence. But rapidly changing technology, compared to the relatively slow rate at which the professional community and responsible authorities are able to adopt new standards and regulations, makes it difficult or impossible for facility designs to be both up to date and in conformance with codes and guide specifications. Many federal agency design manuals and guide specifications, for example, are reviewed and updated on a 5-year cycle. Other design guidance may be updated on different cycles. The National Electrical Code, for example, is updated every 3 years, but most ASHRAE and ANSI[12] codes and standards are updated when participants determine that such change is needed rather than on any regular periodic basis.

Computer technology is helping to support more frequent updating. Work by the Army Corps of Engineers, for example—focused on maintaining up to date technical manuals, regulations, and specifications—has evolved into an on-line system that significantly cuts down on time needed for review. In an activity initiated by the NAVFAC, several federal agencies have joined to support development of the Construction Criteria Base (CCB), a compendium of agency design criteria stored on compact disk[13] and updated quarterly.

Legislation (Public Law 100-678) mandates that agencies use national model codes and standards wherever possible, and it has been suggested that federal agencies simply adopt local building codes or commercial standards for all aspects of facilities for which such codes or standards are available, rather than develop comprehensive design guidance for each agency. Several agencies have, in fact, taken this approach. However, there is still the problem of assuring that local codes remain current—a particular challenge in the case of some smaller jurisdictions. (A BRB study of these matters has been documented. See Building Research Board, 1989, reference.)

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[12]American National Standards Institute (ANSI) and American Society of

Any facility can become obsolete, but those types of facilities that serve more rapidly changing activities (such as hospitals, laboratories, and schools) are particularly susceptible to the problems of obsolescence. Mission-oriented agencies and other owners of large inventories of such highly susceptible facilities can benefit from the effort to develop broader insights into design configurations that are better suited to avoiding or delaying obsolescence. The VAHBS is an example of taking such a generic approach to a particular facility type.

Research laboratories in both corporate and educational settings face problems similar to those of hospitals, for new procedures and technology can motivate researchers to change equipment and increase their use of sophisticated electronic instrumentation, which, in turn, places new loads on electrical and ventilation systems. (By some estimates, as much as 60 percent of laboratory building volume may be devoted to mechanical systems.) Although no single agency or other owner has motivated development of a research-lab equivalent to the VAHBS, designers and owners are finding that certain facility characteristics are consistently better suited to managing obsolescence.

A most notable case is the Salk Institute in La Jolla, California, designed by Louis Kahn and built between 1964 and 1966. The building has been cited as "a wonderfully flexible building."[14] Its interstitial floors and separate office units have made the process of renovation, undertaken at 3-year intervals, relatively easy. However, some critics suggest its construction was excessively costly.

Lessons learned have appeared in newer buildings. One typical case—the Noble Research Center in Stillwater, Oklahoma—has laboratories designed as rows of modular units that can be combined to provide research areas of various sizes (London, 1991). Another example—the AT&T Solid State Technology Center in Breinigsville, Pennsylvania—has laboratories developed as 10,000-square-foot spines coming off of a central hall. The long spaces, which can be used as single units or subdivided, are split lengthwise by a service corridor that has a service tunnel under its floor. Supplies are delivered and waste is removed through these passageways (Slatin, 1991a,b).

The spread of open-plan office building designs and modular furniture represents a similar search for increased ability to avoid or delay obsolescence. Design approaches for other facility types might be found if a means can be

many facilities. For example, the Army's Construction Engineering Research Laboratory (CERL) has devised a database that could be such a means; the data base summarizes building repair costs by task, by component, and by system for Army projects. In so doing, the database can provide insights on the costs of obsolescence associated with certain building features. With additional input on the reasons for change, over—time and across a wide spectrum of structures—this information could help pinpoint key change agents and the areas where effective management approaches could be developed. The General Services Administration (GSA) real property inventory classifications could serve as a framework for characterizing facilities types (Federal Register, 1989a,b).

Using Integrated Building Systems

Another possible lesson suggested by the VAHBS and the Army's IBS is that integrated building systems may offer benefits as a general strategy for avoiding obsolescence. There have been several notable attempts over the past 30 years to develop systems that are more adaptable than the traditional steel or concrete frame construction. One of the earliest was Stanford University's School Construction Systems Development (SCSD) project (see box). A parallel (but unrelated and less successful) effort was the University of California's University Residential Building System (URBS).

More recently, the U.S. Postal Service developed the Kit-of-Parts as a "building system process" to be used for a variety of postal facilities. Six basic modules, having 8,400 to 35,000 net square feet of space, can be assembled to respond to a diverse range of functional needs. The it is computer based and comprises drawings, specifications, schedules, and other documentation necessary to take a designer from design to site-specific issues. The individual module types reflect the Postal Service's studies of the mail-handling functions, resulting, for example in definition of a 20-foot-square bay size for the optimum workroom. Actual construction uses conventional building components and accommodates various facade materials to harmonize with the local environment. Like the VAHBS, the Kit-of-Parts is a recipient of a Federal Design Achievement Award.

The most successful examples of highly standardized integrated building systems are those for which there is sustained demand for construction of multiple installations. Arguments against such building systems include the time

SCHOOL SYSTEMS FOR FLEXIBILITY

The School Construction Systems Development (SCSD) project—initiated in 1962 with funds from the Ford Foundation's Educational Facilities Laboratories—was intended to reduce construction costs; improve the ability to accommodate change; enhance lighting, acoustics, and air conditioning standards; and demonstrate the viability of involving manufacturers in building research based on a common set of modular specifications. The project involved school boards, architects, educators, and industry representatives in extensive programming, development of some 200 pages of performance specifications, and subsequent construction (Spring, 1964).

The project produced designs for components of the structure, integrated ceilings, an air conditioning system, and three wall/partition alternatives that were estimated to cost some 18 percent less than the same elements in a conventionally built school. In addition, project architect Ezra Ehrenkrantz asserted that each of the new components would provide "better performance than the conventional construction it replaces."

The folding truss and roof plate system could span up to 70 feet, with trusses 5 feet on center and a corrugated steel deck substituted for a top chord. This design reduced the steel needed from 6 to 4 pounds per square foot. In addition, 10-foot-wide modules had hinged pivot joints so that they could be shipped flat, lifted into place, unfolded, and braced with diagonal tension bars. Modular lighting and air conditioning were designed to provide effective service in a variety of settings the structure enabled.

To maximize flexibility, interior partitions were required to fit anywhere on a 4-inch-square planning grid. The fixed/demountable wall system consisted of gypsum panels sandwiched between prefinished steel sheets. Each panel was clipped onto steel studs, and working surfaces—chalkboards and tackboards—could be included as integral elements of the design. Folding panel walls were constructed in their own column and truss frame so that no additional reinforcing was needed for their use. Accordion walls also were self-supporting, a standard product modified to improve its acoustical qualities.

An initial mock-up building was erected on Stanford's Palo Alto campus. Based on that initial experience, 22 schools were constructed by 1967 using the SCSD system.

institutions today, socially, politically and economically, is so swift that a large scale systems program which is dependent on long-term commitment and advance decision making is not viable" (Arnold, 1972).

accommodate changed uses, more intense uses, and new service systems—an explicit design goal can assure that the resulting facility is better suited to accommodate future programmatic changes or operational modifications.

The Department of Energy, for example, has revised guidelines addressing design details that can enhance flexibility, and NAVFAC is developing similar guidelines. The latter's Flexibility Mandate highlights the use of such features as raised floors, cellular systems, and power poles that can help provide needed flexibility. The CERL is working to develop flexible facilities design guidance that will allow easy modification or renovation of government structures without sacrificing the quality of the interior space.

Richard Rodgers's design philosophy and its demonstration in the Lloyd's building, already noted here for its flexibility in accommodating change, incorporated six attached towers for elevators, stairs, and other services, including toilet pods. Underwriting is handled in four galleries around a soaring atrium, and up to eight more galleries can be added as needs expand. (Indeed, as the building was being designed, business grew five times faster than Lloyd's highest projection, so four galleries were built rather than the initially planned two.) Similarly rapid growth of the Hong Kong Bank reportedly made flexibility a primary design goal in Norman Foster's 1986 design for that organization's new high-rise facility in Hong Kong (Cathcart, 1991).

Rodgers's design for the P.A. Consulting Group labs, built in 1975 near Princeton, New Jersey, also involved a low, glass-sheathed steel frame with exterior services and interior spaces unencumbered and easily modified. The owner considered the building's openness a productive asset because it encouraged interaction among the scientists of different disciplines working in labs. None of the interior walls are fixed, so the layout can be changed periodically. Open spaces, private conference rooms, and mechanical shops can be moved by shifting the panels that fit into grooves in the structure's beams. One of the more dramatic illustrations of this flexibility occurred when, unforeseen at the time of the building's design, biotechnology labs were added. Today, this kind of facility represents 25 percent of the building's space, and the building has been extended twice without interrupting operations (Caplan, 1988).

Adaptive Details That Enhance Flexibility

making their use increasingly advantageous. These design details fall into several broad strategic categories.

Unconstrained Interior Space. Constraints on interior space expansion may be imposed by structural or service (e.g., mechanical, electrical, and/or telecommunications) subsystems or by site characteristics. Provision of large, column-free areas gives maximum flexibility in moving partitions, and 24- to 30-foot column spacings continue to provide such areas without excessive increases in structural costs. Indeed, specialized users' needs, combined with increasingly economical higher-strength materials, often make use of longer clear spans (e.g., 40 feet) practical. Providing areas with increased floor load capacities also enhance responsiveness to changes in functional relationships within the user's organization. Assuring that exterior walls of those areas that may need expansion remain free of site obstructions similarly eases future change.

Accessible Service Areas. Segregation of services from user-occupied space reduces constraint on the user space but, more importantly, facilitates modification and updating of services. Raised access flooring and interstitial ceiling space are becoming routine design features of even small buildings. Floor-to-floor distances of 15 to 16 feet are typical to accommodate this space.[15] Clustering services into uncrowded service and mechanical bays or "canyons," particularly on the building periphery or along concentrated spines, facilitates access and minimizes conflict with interior space partitioning. Access to switches and other control devices for telecommunications, HVAC, electrical, and lighting subsystems is pivotal to the ability to change these subsystems as new technology is introduced. In general, organized plans for utility locations are needed to make accessible service areas fully effective.

Modularity. Separation of major user areas into zones served by independent mechanical (e.g., chillers and blowers) and electrical (e.g., transformers and control panels) components facilitates equipment updating and modification. It also permits greater control in heating or cooling and lighting of the building. Modularity of plumbing elements can produce similar benefits in laboratories or other facilities where plumbing is a major investment and subject to rapid change. Changeable, movable, and demountable enclosure and partitioning systems, finding application in a broadening range of building types, enhance

as the American Institute of Plant Engineers, the Association of Physical Plant Administrators, the Building Owners and Managers Association, the Intelligent Buildings Institute, and the International Facilities Management Association, could help by framing integrated facilities standards that will encourage building systems compatibility and component interchangeability.

Shell Space. Allowing for expansion by constructing "extra" structure, foundation, and unfinished enclosed space increases initial cost but offers substantial reductions in life-cycle costs of obsolescence. Few design elements highlight so clearly the design tradeoffs to be made between present and future costs. However, this approach conflicts with traditional facilities budgeting and procurement, which focus on first cost alone, preventing the effective consideration of these tradeoffs by dividing management responsibility.

Using Prototypes to Test Performance

Sometimes it is difficult to foresee how people will respond to particular configurations of space and furnishings in a facility, under actual working conditions, and how their response will, in turn, influence facility subsystems performance. Equipment manufacturers and owners and designers of large facilities (or portfolios of similar facilities) can benefit by developing full-scale mock-ups of rooms to test user and subsystem response. Such prototypes allow testing of alternative work patterns and subsystem characteristics that reflect possible future demands on the finished facility. This testing also provides a basis for projecting the implications of new technology that could influence facility obsolescence. In the design of the 500,000-square-foot CIGNA Corporation headquarters building in the 1980s, for example, the design team used a 5,000-square-foot office mock-up to test lighting, office furniture, and a variety of design details for both user response and construction difficulty (Lemer, 1991). Such prototypes may help to extend the service life of the facility with respect to its first use.

Sizing Components to Serve Demand Growth

The principle reflected in the development of shell space can be applied to other facility components that are very difficult or expensive to change at a later date (i.e., structural floor load capacity, and capacity of main trunk air ducts).

branch ducts or fans can be designed to be removed and changed at minimum expense as the building use changes.

Recent growth trends in uses of telecommunications, data processing, and other electrical equipment suggest that substantial allowance for demand growth is prudent. However, increasing efficiencies and emerging control technologies make it difficult to estimate with confidence what future growth rates will be. In addition, properly sized and arranged grounding systems—frequently overlooked components of telecommunication, data processing, and other electrical equipment systems—are needed to support safe expansion.

ACTIONS IN CONSTRUCTION

The construction stage of facility development has relatively less impact on obsolescence than do other stages but is important nevertheless. Failure to achieve the quality in construction that is envisioned in design can lead to a more rapid decline in facility performance and earlier onset of obsolescence. Effective construction quality assurance will enhance the likelihood that obsolescence is avoided or delayed.[16] Similarly, substitution, during construction, of materials or equipment specified in design should be done with care, in order to avoid inadvertent changes in performance that will foster earlier obsolescence.

Separating Procurement of Sensitive Components

In some cases the time period between development of design specifications and procurement during construction is similar in length to that between successive generations of products embodying new technology. Electronic control components, medical equipment, and data transmission and networking devices are examples in which new generations of products are appearing at intervals now approaching 1 to 2 years. In such cases delaying specification and procurement until immediately prior to installation can help to assure that the facility is not judged to be obsolete when construction is complete. Government agencies can accomplish this by designating such components as "government-

Commissioning

Commissioning is a more-or-less formal activity, commenced at completion of construction and often including initial user occupancy, that is intended to check functional subsystems, to determine that the facility is functioning properly, and to undertake any necessary remedial action. The activity typically spans a period of 6 to 12 months.

Although commissioning is primarily a quality assurance activity, it can serve in a manner similar to POE, that is, to facilitate adaptation to user change and to feed information useful for dealing with obsolescence into subsequent design and facility operations. Owners and designers must be conscious of the need to make provisions for equipment and fittings to support adequate commissioning, such as pressure and voltage check points, access plates, and other details that may be used primarily to assure proper initial functioning of installed systems.

ACTIONS IN OPERATIONS AND MAINTENANCE

Management action to avoid or delay obsolescence becomes practically important in the facilities operations and maintenance stages of the life cycle. In these stages the owner and user can act to identify external changes that may signal the onset of obsolescence, while at the same time operating and maintaining the facility to achieve performance according to design intent.

Good maintenance practices, in particular, have an effect similar to that of quality assurance in construction: enhancing the likelihood that performance will indeed conform to design intent. Responsibility for good practices—and for recognizing many of the factors that may lead to obsolescence—rests primarily with the facility manager and maintenance staff. Training of maintenance staff, preparation and updating of maintenance manuals, and use of appropriate materials in maintenance activities thus contribute to avoiding the costs of obsolescence.

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[17]However, as one reviewer has noted, using such methods without adequate

condition monitoring, document management, and maintenance scheduling can be linked in networks with other building automation and security systems. These systems provide a wealth of useful information that can help the facility manager detect problems that could presage obsolescence.[18]

Using Postoccupancy Evaluation in Facility Management

Postoccupancy evaluations (POE) can help in both delaying obsolescence and extending an existing building's service life, when this after-the-fact assessment is used to make adaptations in the facility or its operations. Georgetown University, for example, uses a "Facility Survey" to track the expected life of building systems as well as the schedule and estimated costs of anticipated replacement. In another case, the H.E. Butt Grocery Company in San Antonio has established a POE process involving interviews, questionnaires, analysis of work records, and visits to employee work spaces to support reprogramming of the company's headquarters facility at intervals of about 5 years (Stubbs, 1989).

The CERL is working to develop the concept of a Building Performance Interaction Model that would define, for office facilities, the optimal relationships among thermal comfort, lighting, acoustics, air quality, and spatial configuration. Such a model, used as a basis for POE, would facilitate comprehensive development of office environment "report-cards," which could be used to educate users and managers about how to achieve performance approaching the optimum from their facilities. These report-card evaluations could serve as early warnings of changes that may lead to obsolescence. The goal is to devise a self-reporting survey instrument that users would complete, and that would partially or entirely avoid the need for experts in preparing these report cards.

Adapting for Reuse

When the "fit" between facility and user deteriorates, changing the facility's use often is a reasonable strategy for dealing with this type of obsolescence. This "adaptive reuse" of obsolete structures has become increasingly popular in the United States, particularly where facilities have some historic value. Taking

a structure whose service life has been exhausted and giving it a new function is one of the most dramatic responses to obsolescence. Although few cases approach the scope of architect Renzo Piano's proposed reuse of the 1925 Lingotto Fiat factory (a projected-mixed-use facility combining commercial, industrial, and educational institutions), earlier occupancy and savings on reuse of sound and current components of the structure are among the factors that make this strategy appealing. Conversion of an old grocery store into an outpatient medical center in Phoenix, for example, involved alterations to facades, and interiors, and to mechanical, lighting, and electrical components, as well as the addition of a sprinkler system, yet it was estimated to have saved more than $200,000 and was occupied 6 months sooner than a new structure could have been (Commercial Renovation, 1988). A study of Michigan factories concluded that the these facilities could be redirected and renewed for as little as one-tenth the cost of new construction, and such major corporations as Burroughs and General Electric have garnered praise for successful adaptive reuse of their obsolete buildings (King and Johnson, 1983).

Obviously, adaptive reuse, to be viable, requires that an appropriate new use for the facility be found.[19] As a matter of public policy, tax incentives may be used to enhance the viability of a broader range of alternative uses. However, sometimes facility location and the possible presence of hazardous materials may limit the appeal of this approach to accommodating change.

Managing the Facilities Portfolio

Organizations with a large facilities portfolio and diverse programmatic requirements have the greatest opportunity, in principle, for gaining the benefits of effective reuse. On large campus installations (e.g., military bases, and universities) adaptive reuse can become a significant continuing staff responsibility. In general, it is essential that these installations have a good recorded inventory of the portfolio, including current condition assessments and functional subsystem characteristics. Using shorter terms for leasing and cost recovery calculations, particularly within the context of agency or corporate strategic planning, facilitates management decision-making in dealing with obsolescence.

When obsolescence does occur in a facility subsystem, the user or owner typically pursues the strategy of "making do" for a period of time. Depending on the costs, this frequently may be a most-effective strategy. Making do often involves finding low-cost ways to supplement performance that is no longer adequate, and there are a variety of products designed to support this approach to reducing the costs of obsolescence. For example, installing clear polymer sheet over windows reduces energy loss, and using portable electric heaters can make work areas tolerable in facilities with obsolete or otherwise inadequate climate control systems.

Making do generally is a short-term strategy with high user costs. Eventually, high complaint levels, loss of revenue, loss of tenants, or regulatory or legal action motivates refurbishment (or demolition) of the facility. However, a facility owner can permit and encourage users to modify the facility to forestall obsolescence, as they would define it. Sometimes efforts by the owner to improve facility users' morale or to otherwise shift their overall psychological satisfaction with a situation of which the facility is one part will reduce the costs of obsolescence.

ACTIONS IN REUSE AND RETROFIT

In many cases the owner or user's fundamental response to functional obsolescence is changing a facility's interior configuration. Faced with growth, downsizing, or reorganizations, or faced with the creation of new operations and the need for different spatial relationships among employees, these users or owners tear down some walls and put up others, and rearrange work stations and files. Sometimes a more comprehensive retrofit is undertaken, and changes include early replacement of electrical or communications systems, HVAC controls, life safety and security systems, lighting, elevators, and even exterior cladding. In such cases some facilities permit the changes to be made relatively efficiently and economically, with less disruption to ongoing operations and lower costs to the building's owner and occupants. As distinguished from adaptive reuse, the basic use remains unchanged, and the facility's users hope to continue operations, with as little disruption as possible, during the course of the project.

disabled children currently are under development and will be important in some instances to making judgments regarding building obsolescence.

The costs of extensive retrofit and renovation may be very high. One committee member described a teaching hospital where costs of $500 to $1000 per square foot were incurred to renovate (owing to the need to protect ongoing operations and sensitive equipment and to other problems) when new construction of similar space would have cost perhaps $200 per square foot. Such cases often reflect the premium that must be paid when demolition and new construction are not possible and obsolete structures must be altered to meet current needs and current codes.

However, experience and research show that, even for major changes, careful planning and design can lead to retrofit and renovation costs closer to—and less than—those of new construction for facilities that can accommodate the change effectively (Building, 1985). For example, a Corps of Engineers study of proposals for a total renovation of the Reynolds Army Hospital at Fort Still, Oklahoma, calculated that the estimate for the most desirable renovation was 97.53 percent of the cost of new construction (U.S. Army Engineer District Corps of Engineers, 1984).

The many and complex factors that determine relative cost and viability of retrofit and renovation defy easy analysis. The Singapore Construction Industry Development Board noted that the average age of facilities for which major retrofits are undertaken in that island nation is 13 years, and others have suggested that it may not be viable economically to undertake an extensive renovation of structures over 30 years old (Fong, 1990; Lockwood Green Engineers, 1989). However, some professionals have found that the older a building is, the easier it is to retrofit, because uses for which older buildings were designed typically were less specialized and sharply defined than they are today. Schedule, budget limitations, floor-to-floor heights, access, the presence of asbestos, energy costs, and who pays for operating costs—as opposed to construction costs—are among the factors influencing the evaluation of retrofit and renovation alternatives.

The committee received information from Public Works Canada, a government agency, that work is ongoing to develop generic guidelines for evaluating rehabilitation projects. Procedures for conducting life-cycle costing analysis of a rehabilitation project, including methodologies for evaluating the remaining useful life of building systems, will be examined. Building electrical and mechanical systems are included in the study. Historical structures are

RESPONSIBILITY FOR ACTION

A variety of people must act to avoid or delay facilities obsolescence and its costs. As has been explained, extending service life and avoiding obsolescence are concerns that should be addressed not only before a structure is built—during design and procurement—but also after it is completed, through operations, maintenance, and refurbishment to accommodate functional, technical, economic, and social and political change.

Owners pay many of the costs of obsolescence, and have the primary responsibility of managing their facilities in ways to avoid those costs. However, users of facilities—often not precisely the same people or organizations as the owners—often are burdened with costs of obsolescence as well. Facilities planners and designers should prepare plans that foster an appropriate flexibility and balance among initial investment and future expense to accommodate future change in owners' interests, users' needs, technology, and regulations.

However, as was discussed in earlier chapters, several characteristics of the system that delivers the services of facilities to users (i.e., the design-construct-manage system) make it difficult to sustain action to avoid obsolescence: separation of owner and users; separation of responsibilities for design, construction, and management. These include separation of responsibilities for costs of construction and operations and maintenance; myriad professional groups, trade organizations, and manufacturers...the list goes on. Many of the strategies for avoiding obsolescence involve at least some effort to bridge the gaps among the various individuals and groups concerned with the problem.

The procedures and administrative framework within which federal agencies must work frequently make these problems especially challenging, and there are other problems unique to government agencies (some have been mentioned in previous discussion). These are the topics of Chapter 4.

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4

AVOIDING OBSOLESCENCE IN PUBLIC FACILITIES

The ultimate owners of federal and other government facilities are the taxpayers. Government agencies seeking to use facilities to serve their various missions have the responsibility of protecting and achieving a high return on the public's assets. However, these agencies also must work to achieve other government policy objectives that give rise to unique procedures for planning, budgeting, procurement, and management of design and construction. These procedures and the administrative framework within which agencies must operate influence how government agencies may act most effectively to avoid obsolescence and its costs in public facilities. Congress and other responsible legislative and executive authorities, as well as the agencies immediately responsible for facilities, influence the development and use of public facilities and their costs.

At the federal level and in many states, the public facilities development process differs somewhat from the generic project life cycle as discussed in Chapter 3 (i.e., from initial planning through operations, maintenance and reuse). In public facilities there typically are legislative approvals required, multiple agencies involved, and government objectives served, that are unrelated to facilities (e.g., open competition, and equal opportunity). Actions to avoid

development process.[20]

PUBLIC FACILITIES PLANNING AND FISCAL PROGRAMMING

In federal and many other government facilities development processes, the earliest stages have to do with establishing the authority and the budgetary provisions to undertake new construction or substantial reconstruction. Most federal agencies must seek congressional approval for each individual project having an anticipated monetary value exceeding a specified amount, and this amount for some agencies is very low.[21] The terms "planning" and "fiscal programming", used here, refer to the analysis and decision making associated with these authorizations and in many (and perhaps most) cases do not involve physical planning and spatial or functional programming that design professionals undertake. Activities at this early stage primarily are the agency's responsibility, and the committee's recommendations for actions are intended primarily to enhance agencies' foresight and ability to prepare for change.

Scanning for Change

Agencies should assign specific responsibility for "intelligence gathering," that is, monitoring scientific and regulatory trends and changes in practice that may cause obsolescence. Such monitoring may be made a facet of an individual's job description and performance rating, or it may be assigned to a specific organizational unit. The role may be similar to that of "ombudsman" or technological "gatekeeper."

Along with scanning for trends that may lead to obsolescence, the responsible individuals or offices should develop information and training systems to disseminate new information to decision-makers who represent user and procurement interests and to designers engaged to develop government facilities. In-house and interagency seminars, memoranda, and newsletters are

particularly those appointed to serve for short periods of time (in facilities terms, less than 3 to 5 years) in government agencies—may have relatively limited contact with facilities issues and therefore, limited appreciation of long-term consequences of decisions in programming, design, and construction stages of a facility's life.

Strategic Planning

Agencies should undertake explicit strategic planning to identify the potential for future expansion or contraction of facilities requirements within the context of likely budget limits, opportunities to secure alternative user groups, or multiagency facilities uses. Organizational planning should be tied more closely to architectural programming and facility portfolio management.

In relating strategic and fiscal planning more directly to facilities planning, agencies should develop ways to incorporate lessons learned in current projects—from site observations (e.g., during construction and commissioning) and postoccupancy evaluations—quickly into agency design guidelines. Evolving computer-based information systems (as mentioned in Chapter 3) will facilitate the more frequent updating of guidelines. The feedback of information and updating of guidelines should focus particularly on those building types that are most likely to require greater flexibility to accommodate future increases in space demand or functional changes or that are particularly prone to technological change (e.g., hospitals and labs).

Agencies encountering recurring obsolescence in particular types of buildings should consider developing or adopting standard design and management strategies (e.g., the VAHBS for hospitals or the U.S. Postal Service's Kit-of-Parts) that have proved their value in enabling action to delay or avoid obsolescence. When an agency's building portfolio or other factors preclude standardization at strategic levels, the agency should document building case studies, in terms of design details and management practices, that have been successful in providing flexibility and responsiveness to change. Professional organizations such as the American Institute of Architects (AIA), American Society of Civil Engineers (ASCE), Building Owners and Managers Association (BOMA), and Urban Land Institute (ULI), could assist the agencies, and the profession as a whole, by disseminating project case studies dealing with

In strategic planning, transfers of facilities among agencies and among departments of large agencies warrant attention. Optimum utilization of the government's total portfolio is an effective means of reducing the costs of obsolescence. An interagency clearinghouse function should be considered, within the General Services Administration or the Office of Management and Budget, to facilitate this activity.

Shortening the Development Process

The public facilities development process, from initial planning to occupancy, often is longer in the private sector (3 to 5 years versus 18 to 36 months), and the chances that a facility will be "obsolete before it is finished" increase as this time lengthens. Agencies should work to control and reduce the time needed for planning, design, and construction. Components particularly prone to obsolescence may be designated early in the process as "government furnished" to allow for their procurement as late as possible and thus reduce the likelihood of early obsolescence.

The need to secure executive and legislative approval of projects, combined with a desire to avoid having to request changes and reauthorization, leads public agencies frequently to try to establish all characteristics of a project at too early a stage in the development process. This effort frequently leads, in turn, to a resistance to making desirable changes during final design and to issuing reasonable change orders during construction. These tendencies become a problem when shifts in users' needs or other changes occur during the development process. Agencies need policies that allow for updating of designs to avoid obsolescence, that is, even during construction, and legislative oversight groups should recognize the valid need for such changes.

PUBLIC FACILITIES BUDGETING FOR FLEXIBILITY

For public facilities, actions by Congress or by other funding authorities may influence an agency's ability to deal with obsolescence. Failing to allow for flexibility, may have serious consequences especially at the stage where budgets are fixed.

Agencies should include in their budgeting and preliminary design a

facility databases can support such analysis. Budget authorities then should be encouraged to commit to the preferred strategies as a part of the costs of owning facilities. Operation and maintenance "trusts," renewal sinking funds, and other mechanisms for earmarking funds should be used, if necessary, to make this commitment effective in practice. Research to support flexibility, particularly data collection and analysis on space utilization, systems function, and user satisfaction should be supported and fed into subsequent planning and design.

In addition, agencies should seek and be given budget allocations to permit inventory stockpiling of replacement parts and supplies that could forestall obsolescence of larger subsystems. Inability to obtain replacement parts is an avoidable cause of obsolescence.

SETTING FACILITY DESIGN GUIDELINES AND OTHER PREDESIGN ACTION

Federal agencies are responsible for establishing their own facility design guidelines and criteria. Some agencies draw heavily on the national codes and standards that provide the basis for most local building codes and professional design guides, but other agencies have their own extensive, and sometimes unique, controls. In either case, however, federal agencies seeking to manage facilities in such a way as to avoid obsolescence have a particular responsibility to assure that their criteria and guidelines are up to date and do not refer to obsolete procedures and products. Agencies should prepare for design by assuring that their criteria reflect consideration of trends of changing technology and likely future needs, particularly regarding mechanical, electrical, and communications systems. Specific reference should be made to the costs of obsolescence and the agencies' desire to avoid those costs.

Agencies should continue to support development of computer-based automation of government guide specifications, to facilitate search and discovery of criteria most likely to face change, and to help to resolve unnecessary differences among various agencies. Increased use of postoccupancy evaluations can support that effort. In addition, agencies should support predesign analysis of critical projects to foster adaptability, and they should encourage designers to adopt CAD sketch systems, generic facility design charettes, or other techniques for such analysis.

FACILITY PROGRAMMING, DESIGN, AND CONSTRUCTION

At this time, public and private facilities development processes are largely similar, and the designer is primarily responsible for actions to minimize the costs of obsolescence. However, the owner—agency or otherwise—must work with the designer to assure that the design is sensitive to the owner's potential future interests and needs. The designer should work with the agency to define explicitly what performance ranges for the facility are acceptable, in order to provide a sound basis for considering how expectations may change in the future, and the users of the facility, if different from the owner, should be involved in this effort.

The designer also should be sensitive to any owner-specified criteria that may limit flexibility of the final design, such as high required net-to-gross floor space ratios and programs with no provision for service access and retrofitting. The program should have the dimension of time incorporated, making it a life-cycle document. The designer should be sensitive as well to aspects of the project or its major components that may indicate that avoidance of obsolescence will be facilitated by construction phasing to reduce time between procurement of high-technology equipment and facility commissioning (e.g., use of "government-furnished-equipment" (GFE) procurements).

In design development, agency personnel, including user agency personnel, should work with the designer to assure that flexibility or adaptability is understood explicitly to be a worthwhile design goal. Including flexibility within the designer's terms of reference will aid in accomplishing this. The designer should highlight design elements that enhance flexibility, in order to improve the user's and owner's understanding of how the facility may be adapted to future change. CAD systems that support exploration of a design's flexibility and facilitate development of an accurate facility operations database are valuable tools in this effort. At the end of construction, agency personnel should assure adequate commissioning of the facility, including systems start-up, occupancy walk-through, documentation and training for operations and management, and punch-list follow-up, so that facility performance reaches optimal design levels.

postoccupancy evaluation programs, collection of good facilities inventory data, strategic planning, and other practices that help avoid rapid performance deterioration and that optimize facility utilization.

ACHIEVING OPTIMUM PUBLIC FACILITIES USE

Public facilities are valuable assets that can provide long and high-quality service if they are utilized effectively. Avoiding obsolescence and its costs, although only one aspect of the complex task facing facility professionals seeking to assure effective utilization, has grown increasingly important as change has become more rapid in both the technology of facilities and the demands that facilities are expected to serve. It is impossible to foresee all of the many changes likely to occur in the future, but the committee agreed that there are lessons to be learned, particularly regarding designing for the flexibility to accommodate change.

The details of individual facilities provide the crucial focus for efforts to avoid obsolescence. However, a first step toward more effective management is sensitivity to the problems of change and the possibilities for accommodating change. The committee hopes that its work will enhance this sensitivity in government decision-makers and will motivate more effective action to avoid the costs of obsolescence in public facilities.

APPENDIX A

BIOGRAPHICAL SKETCHES OF COMMITTEE MEMBERS AND STAFF

DONALD G. ISELIN is a consultant specializing in engineering management. He graduated at the head of his class from the U.S. Naval Academy in 1945, earned his Bachelor's and Master's degrees in civil engineering from Rensselaer Polytechnic Institute, and completed the Advanced Management Program at the Harvard Business School. He retired from the U.S. Navy in 1981 as a rear admiral after serving as commander of the Naval Facilities Engineering Command and chief of civil engineers of the Navy. He has served in top-level positions for major international engineering firms and has been active in national professional societies. He is a member of the National Academy of Engineering.

J. PHILIP ANDREWS, FAIA, is a principal of Damianos Brown Andrews Inc., architects and planners, and a registered architect in Pennsylvania and Ohio. He received his B.Arch in 1962 from Carnegie Mellon University and has more than 28 years of diversified management and planning experience. Formerly director of technology development and director of corporate design with Westinghouse Electric Corporation, Mr. Andrews was instrumental in designing and implementing information systems, personal computer networks, and other systems for productivity enhancement that bring together architecture and the business of a large corporation. He has served as an officer or member of the board of trustees of the Pittsburgh

GARY G. BRIGGS is the senior vice president and head of the Mechanical Department of Charles E. Smith Management, Inc. Mr. Briggs holds a B.S. in physics from Drexel University. He provides technical services and consulting to the operating departments of the Smith Companies regarding mechanical plants and operations, fire safety and security, elevators and escalators, structures and envelopes, and energy management. The Smith Companies manages and owns more than 150 properties, including office buildings, residential properties, retail malls, and recreational facilities.

R. ELIZABETH EVERS is a senior attorney with the Marriott Corporation's Senior Living Services Division. An urban planner as well as a lawyer, Ms. Evers holds a J.D. degree from the Catholic University of America, a Master's in urban and regional planning from the George Washington University, and a B.A. in psychology and sociology from Slippery Rock State College. She has broad experience in many phases of real estate development, feasibility analysis, zoning and land use control, and environmental impact analyses for major development and transportation projects, and she has published a number of articles on historic preservation.

WILLIAM K. GAY is department manager of Special Systems Integration for the Sverdrup Corporation and is an expert in solving the problems of fitting sophisticated energy management; fire and life safety; security; and voice, data, and video telecommunications systems to buildings. He holds a Bachelor of Civil Engineering degree and a Master of Engineering degree in civil engineering management. He also has received training at the Defense Systems Management College and is a certified U.S. Army Acquisition Manager. Mr. Gay is the chairman of the Technical Committee of the Intelligent Buildings Institute.

GEORGE E. HARTMAN is a principal of Hartman-Cox Architects and is widely recognized as a distinguished designer. He received his B.A. in architecture in 1957 and his Master's degree in 1960 from Princeton University. He has received numerous awards for his work, which includes major buildings throughout the Washington area, and has lectured at many universities and national events. Mr. Hartman has served on many professional awards panels and on the faculties of the University of Maryland and the Catholic University of America.

MIN KANTROWITZ is president of Min Kantrowitz and Associates, Inc., and a specialist in applied environmental design research, facility programming, and evaluation. She is also an adjunct associate professor at the School of

and planning from the University of New Mexico. She has served on the board of directors of the Environmental Design Research Association, is active in American Society for Testing and Materials (ASTM) and other professional organizations, and has published numerous books and articles on user needs and postoccupancy evaluation of buildings.

ROGER E. PANTHER, Ph.D., is president of Facility Development, a Division of Quorum Health Resources, Inc. He received a B.A. in philosophy from Marquette University, an M.A. in hospital and health administration from the University of Iowa, and a Ph.D. in public administration from the University of Southern California. Prior to joining Quorum (formerly a subsidiary of Hospital Corporation of America), Dr. Panther served as the vice-president for planning and programming for Hospital Affiliates Development Corporation, the vice-president of the Swiss Corporation of Hospital Affiliates, and the executive director of the American Hospital of Paris.

LESLIE DEAN PRICE, AIA, is University Architect Emeritus and Director Emeritus of Facilities Development for Georgetown University, where he is also actively involved in research and development as the author of the National Exemplar Program projects funded by several federal agencies. He received his B.Arch. from the University of California and was previously an architect in private practice and advisor to North American Rockwell's Autonetics, Research and Engineering Division. He is special consultant to the Office of the President/Federal Relations Continuing the National Exemplar Leadership for Georgetown University.

GARY L. REYNOLDS is director of Facilities Management and a former temporary assistant professor of mechanical engineering at Iowa State University. He is currently a faculty member of the Association of Physical Plant Administrators Facilities Management Institute. He received a B.S. in engineering science in 1972 and an M.S. in mechanical Engineering in 1979 from Iowa State University. Mr. Reynolds is coauthor of the manual used for the Iowa Class A Energy Auditor Training program, which was subsequently used as the basis for the state of Iowa's life-cycle costing legislation. His current position involves overseeing the application of the life-cycle costing law to buildings constructed for Iowa State University.

JAMES RICH is vice-president of the Sigal/Zuckerman Company, a major real estate developer. He was formerly director of Development for the Pennsylvania Avenue Development Corporation and director of Planning and

WILBUR H. (TIB) TUSLER, FAIA, is senior vice-president of Stone Marraccini Patterson, architects and planners, and has over 30 years of experience in architectural design and programming. He received a B.S. in building design in 1956 and an M.S. in architecture in 1957 from Virginia Polytechnic Institute. In 1958 he earned an M.Arch from the Massachusetts Institute of Technology. He has served as member and chairman of the Board of the Health Facilities Research Program of the American Institute of Architects (AIA)/Association of Collegiate Schools of Architecture (ACSA) Council on Architectural Research and Chairman of the AIA Committee an Architecture for Health, and he has written articles and books on integrated building systems, health facility programming, and project planning.

Staff

ANDREW C. LEMER, Ph.D., is an engineer-economist and planner. Formerly division vice-president with PRC Engineering, Inc., Dr. Lemer is founder and president of the MATRIX Group, Inc., and has written widely on matters of infrastructure, building economics, and development policy, often in conjunction with his work on major projects in the United States and overseas. He received his S.B., S.M., and Ph.D. degrees in civil engineering from the Massachusetts Institute of Technology and is the recipient of a Loeb Fellowship at Harvard University Graduate School of Design. He is a member of the American Institute of Certified Planners, the American Society of Civil Engineers, the Urban Land Institute, and the American Macroengineering Society.

DAVID MOG, Ph.D., is a chemist by training, and currently teaches at the Sidwell Friends School in Washington, D.C.

THOMAS WALTON, Ph.D., is an associate professor in the Catholic University of America's Department of Architecture and Planning. Walton teaches both history and design, with a particular expertise and research interest in corporate architecture and American urbanism. His writings span a range of subjects, from his recent book, *Architecture and the Corporation: The Creative Intersection* (Macmillan, 1988), to articles on the development of Washington, D.C.'s turn-of-the-century Beaux Arts urban plan. He is editor of the *Design Management Journal*, a publication devoted to analysis

APPENDIX B

GLOSSARY OF TERMS

The following definitions have, in some cases, been developed to address the particular considerations of building or facility obsolescence, as discussed by the committee. Readers may wish to refer to the several texts and articles cited throughout this report for additional information on or detailed discussion of these terms.

ACCESSIBLE SERVICE AREAS. Space designed into a facility specifically to facilitate maintenance, repair, and modification of one or more building subsystems. *Interstitial space* (e.g., in ceilings), *raised access floors*, and electrical and mechanical *canyons* are examples of accessible service areas.

ADAPTIVE REUSE. Conversion of a facility or part of a facility to a use significantly different from that for which it was originally designed.

BUILDING. Type of *constructed facility*.

BUILDING PORTFOLIO. A collection of buildings or other constructed facilities managed by a single agency or other owner.

CANYON. Vertical service bays designed to house communications, electrical, and mechanical service distribution equipment in a readily accessible way; a type of *accessible service area*.

COMMISSIONING. An activity, commenced at completion of construction

referred to as an *element*.

CONSTRUCTED FACILITY. The physical product of construction activities, comprising an assemblage of relatively distinct functional *systems*, *subsystems*, *elements*, and *components*.

CONSTRUCTION CRITERIA BASE (CCB). A commercially available compendium of agency design criteria stored on computer-accessible compact disk.

COSTS OF OWNERSHIP. The total of all costs incurred, generally by the owners but also by the users, to obtain the benefits of a facility.

DESIGN SERVICE LIFE. The period of time over which a building or a building subsystem or component (e.g., the roof, mechanical equipment, plumbing, or sheathing) is designed to provide at least an acceptable minimum level of shelter or service, as defined by the owner; typically depends on assumptions, sometimes implicit, regarding satisfactory completion of normal maintenance activities. An idealized *service life*.

ECONOMIC LIFE. The period of time over which costs are incurred and benefits or disbenefits are delivered to an owner; an assumed value sometimes established by tax regulations or other legal requirements or accounting standards and not necessarily related to the likely *service life* of a facility or subsystem.

ELEMENT. See **component**.

HVAC. Heating, ventilation, and air conditioning.

INTEGRATED BUILDING SYSTEMS. Functional *systems* designed specifically to fit and work together as a larger system; intended to provide better *performance* than systems not designed for integration.

INTERSTITIAL SPACE. A type of *accessible service area*, typically space provided between the structural floor panel and a hung interior ceiling; a key element of VAHBS (VA Hospital Building System), a 9-foot floor-between-floors that houses mechanical and electrical components.

LIFE CYCLE. The sequence of events in planning, design, construction, use, and disposal (e.g., through sale, demolition, or substantial renovation) during the service life of a facility; may include changes in use and reconstruction.

LIFE-CYCLE COST. The *present value* of all anticipated costs to be incurred during a facility's *economic life*; the sum total of direct, indirect, recurring, nonrecurring, and other related costs incurred or estimated to be incurred in the design, development, production, operation, maintenance, support,

integrated building systems, in which repetitive use of *components* and *subsystems* facilitates facility maintenance and repair.

OBSOLESCENCE. The condition of being antiquated, old fashioned, or out of date, resulting when there is a change in the requirements or expectations regarding the shelter, comfort, profitability, or other dimension of performance that a building or building subsystem is expected to provide. Obsolescence may occur because of functional, economic, technical, or social and cultural change.

OPENING CONFIGURATION. The specifics of use dictated by the building owner and initial users during the earliest stages of project development; the spatial and *systems* configuration that should be considered as simply the first of many uses for which the building should be planned.

PERFORMANCE. The degree to which a building or other facility serves its users and fulfills the purpose for which it was built or acquired; the ability of a facility to provide the shelter and service for which it is intended.

PERIODIC RENEWALS. Regular changes of items, such as replacing carpets, painting, or overhauling compressors.

PHYSICAL LIFE. The time it takes for a building, subsystem, or component to wear out or fail the "time period after which a facility can no longer perform its function because increasing physical deterioration has rendered it useless."

PLANNED SHORT SERVICE LIFE. A decision that the *service life* of a facility should be shorter than might typically be expected; implies selection of *components* that have low first cost and low durability; similar to the term "planned obsolescence" used in the automobile and consumer products industries.

POSTOCCUPANCY EVALUATION. Collection and analysis of information, particularly from users, to assess how well a facility's performance matches user needs and design intent.

PREDESIGN ANALYSIS. The system of analysis involved in developing conceptual design alternatives and working out a variety of design details before the actual detailed design begins.

PRESENT VALUE. A concept in economics reflecting the time-value of money, in which costs and revenues of future years are expressed in terms of the amounts they would be equivalent to if they occurred in the present year; sometimes termed "discounted value."

PROGRAMMING. Activities that lead to determination of the specific scale,

RETROFIT. The redesign and reconstruction of an existing facility or subsystem to incorporate new technology, to meet new requirements, or to otherwise provide performance not foreseen in the original design.

SERVICE LIFE. The period of time over which a *building*, *component*, or *subsystem* actually provides adequate performance; a technical parameter that depends on design, construction quality, operations and maintenance practices, use, environmental factors, and users' and owners' expectations; not the same as *economic life* or *design service life*.

SHELL SPACE. Space in a facility for which the structural system and typically the exterior envelope are complete but in which other functional subsystems are left for completion at some future time.

SUBSYSTEM. Functional part of a *system*, and often used interchangeably with that term (e.g., heating subsystem [part of HVAC system]).

SYSTEM. Collection of *subsystems*, *components*, or *elements* that work together to provide some major aspect of shelter or service in a *constructed facility* (e.g., plumbing system, electrical system, and roofing system). Also, a set of building *components* specifically designed to work together to facilitate construction (e.g., integrated building system).

WORKSHOP ON ENVIRONMENTAL AND HEALTH REGULATIONS AS SOURCES OF FACILITY OBSOLESCENCE

In the course of its discussions on facility obsolescence, the committee noted that new issues arise regarding both the environmental and health concerns that have an impact on facilities management and adaptability. These issues may render facilities effectively obsolete, especially when government laws and regulations, formally stated agency criteria and guidelines, or the knowledge and methods that comprise current professional practice change substantially from those in effect when a facility was designed and constructed.

Such change may necessitate new or altered materials, building components, and construction procedures, as numerous examples illustrate. Passage of clean air legislation in the 1970s, for example, led to substantial reduction in the incineration of solid waste at individual facilities and, consequently, increased demands on landfill disposal sites. Similarly, concerns about the carcinogenic effects of asbestos have made removal of this once-popular fireproofing material a major expense for many building owners. The forthcoming ban on chlorofluorocarbons (CFCs), fostered by concern for the earth's upper atmosphere ozone layer, is motivating a search for new materials and equipment for climate control and fire suppression in buildings, which may then render obsolete materials and equipment now in place.

These changes in the requirements that buildings must meet constitute one of the most clearly defined causes of obsolescence. Although new government regulations (particularly those adopted as part of a building code) may include

requirements become effective more quickly by influencing the expectations of building users, purchasers, or lenders who will demand—through market decisions—that the new requirements be met. Even if the new requirements do not immediately influence market values or the range of uses to which an existing building may be put, there is an implicit reduction in the performance the building provides, relative to other facilities that meet the newer requirement.

Regulations promulgated during a building's design or construction may necessitate both costly delays and additional work in redesign. Sometimes these regulations are applied to all buildings, requiring that existing structures be retrofitted, with costs at times exceeding those for new construction.[22] Designers who foresee new regulations perhaps could make provisions in their new facilities that would save time and money or would avoid adverse effects when the regulations or concerns actually come into force. Early recognition of new concerns certainly would give responsible officials and the building industry more time to develop technically effective and economical responses that would aid in avoiding obsolescence.

THE WORKSHOP ON FORESEEABLE PROBLEMS

In order to consider whether there are actions that federal agencies or others might take to foresee more effectively these causes of obsolescence, the BRB held a 1-day workshop in Washington, D.C., on July 30, 1991. Participants in the workshop (see box) were invited to discuss the issues of new environmental and health concerns that can lead to obsolescence and, particularly, to address the following questions:

- What environmental and health issues or topics are likely to become significant in public policy or in regulation influencing building design or operation during this decade? What will be the asbestos or PCB[23] of

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[22]Although not really an example of obsolescence, regulations requiring permits for new construction sometimes have the effect of forcing property

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tomorrow? What issues do knowledgeable people foresee as posing threats to health, safety, or environmental quality that may warrant new legislation and regulatory requirements?

- What are the stages or processes through which such topics or issues

indicating a potential problem emerge? How do responsible authorities and policy makers become aware and judge the significance of problems? How long does it take for this process to occur?

- How do these topics or issues come to have a specific influence on building design, construction, operations, or maintenance practices? What roles are played by individual professionals, professional organizations, standards and model code organizations, regulatory bodies, public officials, the news media, advocacy groups, financial institutions (and, in government, budget agencies), or others? Is there value to responding to issues before they are addressed by legislation or regulation? To whom does this value accrue? What are the scope and scale of anticipated impact?
- Is it practical and worthwhile to anticipate and to prepare to act in advance on emerging regulatory or policy issues? Can ways be found to anticipate and to prepare cost effectively for future environmental and occupational health concerns that will affect building design and construction? Can a government agency (or private institution) implement an early warning system? If so, how?

Workshop participants addressed each of these sets of questions in turn and drew primarily on their own experience to suggest answers. The results of the workshop, summarized here, were presented to the full study committee and became a part of the committee's basis for its conclusions and recommendations.

PENDING CONCERNS

A wide variety of potential concerns can be found in the technical literature and the popular press. Table 2 (found in Chapter 2 of this document) summarizes the concerns of which BRB staff and workshop participants were particularly aware. Participants observed that the source of many of these concerns is the increasing sensitivity and sophistication of procedures that measure trace chemicals and fine particles, that detect physiological changes in laboratory animals and humans, and that mathematically correlate observed environmental and health effects with possible causes.

One participant suggested that the newest discoveries in analytical chemistry, in particular, may be a powerful predictor of the environmental or health concerns that will emerge within 3 to 5 years. Other participants proposed that

ISSUE DEVELOPMENT

Of course, the identification of a new concern does not necessarily assure that the concern will become important in public consciousness or that new regulations or changes in building practice will result. The development process of such concerns from initial discovery through scientific exploration, public consideration, and government and private sector response is complex, with many participants and significant uncertainties.

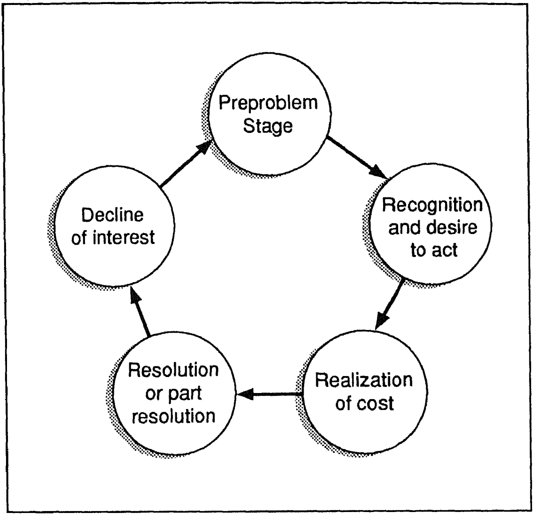

Figure C-1 Down's "issue-attention cycle" characterizes the sequence through which societal problems evolve.

boredom (Downs, 1972). This issue attention cycle is illustrated in Figure 3-1. A problem must be dramatic and exciting to maintain public interest, and not all major social issues go through this cycle. Interest in some issues dies when the cost of addressing them is found to exceed the anticipated benefits. Other issues are resolved, to the satisfaction of a majority of participants, when regulations or other means are adopted. Such issues are unlikely to re-emerge unless new information leads to a significant reassessment of the problem.

In the progression toward resolution or partial resolution of issues, the levels of technical uncertainty will influence the willingness of the public and the professions to accept the costs of taking action. When these uncertainties are substantial, costly actions are justifiable when they have merits beyond those associated with the issue at hand. For example, the banning of CFCs, which contribute to global warming, is said to be worthwhile since it will also slow the degradation of the ozone layer (Skolnikoff, 1990).

Workshop participants noted that issues having a wider impact or a greater level of public interest often will take longer to resolve. When many interests are likely to be affected, political debate may be extensive before a satisfactory resolution is found, particularly at the federal level. It is not unusual for 2 to 3 years to pass from the time articles appear in the press until federal legislation is enacted that addresses the issue at hand.

On the other hand, when there is a strong emotional element to the issue and a clearly identifiable course of action, and when the costs or other adverse effects of that course have limited distribution, issues may be resolved more quickly. For example, the issue of asbestos removal in public schools emerged over a short time period because children were affected, the costs of removal were to be borne largely by local government bodies, and only a few private corporations were directly at risk in matters of legal liability.

The Arlington County (Virginia) School Board, for example, voted for complete removal of asbestos at a cost exceeding by ten times the amount that was recommended as needed to prudently manage risk by encapsulation and selective removal. The board's president explained that whereas the board was prepared to accept the experts' position that removal was not necessary, it was not in a position to educate the public about risk and thus felt compelled to vote in accord with the public's perception on the matter.

Workshop participants observed that the state of California has, for some time, been a bellwether in identification and resolution of environmental and health concerns that influence buildings and building practices. The U.S.

HOW ISSUES COME TO INFLUENCE BUILDING PRACTICES

Environmental and health issues influence buildings and building practice most frequently when they are reflected in building codes or professional design guidelines. Although building codes typically are enacted at the local level, they are based primarily on national or regional models. Unless legislation directs that a particular course of action be taken, study and discussion of benefits and costs of alternative courses will progress within the professional community, generally at a national level, until some consensus is reached.

Issues that are already seemingly well understood and thoroughly addressed in regulation are unlikely to lead to facilities obsolescence. For example, grounding mechanisms for electric wiring have evolved with the introduction of polarized plugs and outlets, but older buildings continue to provide acceptably safe accommodation for users and their new electrical equipment.

In those cases where public or regulatory agency concerns motivate regulations or changes in practice, despite a lack of technical information and generally accepted professional consensus on an issue's severity, the obsolescence impact may develop rapidly. However, once the impact is felt, new information is less likely to lead to substantial additional impact. For example, despite the continued scientific debate concerning the health hazards of asbestos in buildings, many public agencies require removal of all asbestos from older structures undergoing renovation. Similarly, private banks and other lenders often insist on asbestos removal as a condition for providing financing, regardless of whether the responsible building code officials would require such action. Eventual consensus may not change the impact of this issue on existing buildings.

Issues for which information is still being gathered or for which no generally accepted consensus has emerged warrant attention as potential causes of obsolescence. Building professionals have an opportunity in such cases to develop information on likely consequences of various regulatory responses, in terms of obsolescence that may be caused in existing buildings. Although designers may seek to avoid those decisions not matching possible future regulations, the costs of aggressive response to emerging problems may be out

ANTICIPATING NEW ISSUES AND REGULATIONS

The planning and design of government facilities typically occur over a period of 18 to 36 months.[24] From initial planning to occupancy, the time can be 3 to 5 years. Building upgrading and use changes typically occur at 3 to 15-year intervals. Workshop participants noted that environmental and health issues likely to influence facility obsolescence generally evolve over a 3- to 5-year period and that impending changes possibly may be anticipated over such a time period. It seems plausible, then, that designers make a special effort to consider emerging issues that will have an impact on building systems or design features with service lives typically exceeding 5 years. Increased initial costs to avoid future obsolescence of such systems or design features may be more than repaid by future savings.

For example, air conditioning chiller units, expected to provide service for more than 15 to 20 years, currently are available that will accept those refrigerants likely to replace CFCs. This equipment is designed to operate efficiently with the new refrigerants when they become commercially available but will operate suboptimally with refrigerants currently available. Workshop participants suggested that the higher costs of suboptimal operation, incurred over the likely 3 to 5 years until new refrigerants are available, are a wise investment in view of the impending ban on CFCs.

Design features and building systems that normally are substantially altered or replaced at regular intervals can be upgraded to meet new requirements. The owner is then less likely to incur the substantially higher costs associated with failing to consider future change influencing such systems. This special effort involves scanning appropriate sources to detect emerging issues and then assessing those issues' implications for new construction or for reconfiguration and rehabilitation projects currently in planning or design. Such scanning or screening of emerging issues provides the basis for an assessment, as part of the normal design process, of alternative courses of action for avoiding obsolescence caused by environmental or health concerns.

The EPA has a definite role in this scanning process. Agency staff currently are active, in professional forums and through informal professional networks, in alerting designers to emerging environmental problems and likely governmental responses. Plans for establishing a more formal clearinghouse operation have been made as well. However, the Environmental Protection Agency (EPA) have comprehensive responsibility for the full range of environmental and health issues that may have an impact on building obsolescence. The Department of Energy, the Occupational Safety and Health Administration (OSHA), and state and local government agencies are among those participating in efforts to address the problems cited in Table 2, and additional agencies could become involved as new problems are identified.

The principal responsibility for screening falls to the primary beneficiary of the results: the owner and the designers seeking to meet the owner's needs. However, because the effort required may exceed the resources available to the designer on a single project, workshop participants proposed that professional organizations (e.g., the American Institute of Architects (AIA), the American Society of Civil Engineers (ASCE), and the American Society for Testing and Materials (ASTM), and others) may be effective leaders in identifying newly emerging concerns that could lead to facility obsolescence. Workshop participants also suggested that some federal agency, or a group of agencies acting through such an organization as the Federal Construction Council, could undertake this scanning function for federal agencies. Private business also might be able to provide this scanning function as a commercial service. However it is done, there also must be effective communication systems to ensure that information is disseminated to those facilities professionals who can use it.

Some professional and trade groups already have begun efforts that could evolve into such a screening activity. The AIA, for example, has established an environment committee to develop a resource guide for architects, focusing on the environmental implications of various building materials, and the Electric Power Research Institute and the EPA are working together to alert energy engineers to utilities management issues having an impact on the global environment.

Workshop participants agreed that the rates of change in both our knowledge of environmental and health problems and the technology of construction and building systems make it worthwhile to seek to avoid obsolescence over the short to medium term. Designers, whether working for government agencies

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APPENDIX D

PREDICTING PERFORMANCE, SERVICE LIFE, AND PHYSICAL LIFE OF BUILDINGS AND THEIR COMPONENTS

If facilities, components, subsystems, or entire buildings somehow fail or wear out before they become out of date or old fashioned, obsolescence cannot occur. In order to foresee obsolescence, one must consider both the changes in use or technology that cause obsolescence and the loads, aging, and wear that can bring the service life to an end before obsolescence occurs.

Knowledge of the chemical and physical changes that occur as materials age and wear provides the basis for theoretical predictions of service-life duration and performance during that time. Corrosion, fatigue, abrasion, and a variety of other processes may to some degree be forecast for materials in service. This forecasting sometimes is undertaken primarily on a statistical basis, with simple correlations made between the condition of the building materials or element and the parameters, such as temperature or numbers of loadings, that are presumed from theory to contribute to wear and aging. Sometimes a more elaborate mathematical model of the wear or aging process is constructed to provide the basis for data collection and analysis, but the result will still depend on statistical relationships among observable variables.

In a few areas, such as chemical corrosion of steel alloys and ultraviolet-caused changes underlying the weathering of PVC (polyvinyl chloride plastic) components, the mechanisms of aging and wear are sufficiently well understood and observable so that effective design and maintenance practices can be specified to control physical service life. However, even in these few areas, uncertainties of service conditions frequently lead to premature failures, and the likelihood that actual physical service lives may be substantially longer than average leads many facility operators to wait until problems arise rather than to undertake preventive maintenance.

Status of Prediction Models

The effort to predict physical service life in order to develop reliable models for prediction is an area of active research in many countries. Members of such research organizations as American Society for Testing and Material (ASTM) work through standing committees to advance the state of the art in these areas, and they have held a number of international conferences to share information and coordinate their efforts (see Masters, 1985, for example). However, the field is still young.

A major incentive to pursue the complex task of developing service-life performance prediction models is inspired by successes in the field of highways. A boom in system expansion in the United States in the 1950s and 1960s that increased dramatically the scale of the nation's investment in highways coincided with rapid advances in computer technology and applications of systems analysis techniques in civil engineering. At the same time, work by development economists at the World Bank and elsewhere began to demonstrate convincingly the direct contribution that pavement conditions have on vehicle operating costs and, in turn, on economic efficiency of a region's transportation system. These forces combined to motivate research and development efforts that led to establishment of practical pavement management systems, which, after two decades, now are used routinely by many state transportation agencies to monitor highway facilities, to assure maintenance effectiveness, and to schedule rehabilitation and replacement of pavements (Hudson, et al., 1979). Researchers in the field are looking toward evolving present systems into larger, integrated, "total facilities management" systems useful to public facilities administrators

yielded some positive results, have encountered serious problems because neither performance measurements nor life-cycle analysis models are well developed for buildings and their components. The U.S. Army Corps of Engineers, for example, has developed a management system for bituminous built-up roofs (called "ROOFER"), and a number of U.S. and international researchers have developed models that facilitate life-cycle cost management of building energy systems (see Carlsson, 1989, for example), but these efforts each deal with only a part of the complex multicomponent system that a building represents.

References

Carlsson, B. 1989. Solar Materials Research and Development: Survey of Service Life Prediction Methods for Materials in Solar Heating and Cooling. Stockholm: Swedish Council for Building Research.

Haas, R., and W. R. Hudson. 1987. Future prospects for pavement management. Paper prepared for Second North American Conference on Managing Pavements, Toronto, November 2-6, 1976.

Hudson, W. R., R. Haas, and R. D. Pedigo. 1979. Pavement Management System Development. NCHRP Report 215. Washington, D.C.: Transportation Research Board.

Masters, L. W., ed. 1985. Problems in Service Life Prediction of Building and Construction Materials. Boston: Matinus Nijhoff Publishers.

APPENDIX E

HOSPITAL BUILDING SYSTEMS

The Veterans Administration (VA; now the Department of Veterans Affairs) hospital building system (VAHBS) was developed in the late 1960s to be a set of modular planning and organizational rules establishing the relationships among hospital systems and spaces. The functional units are characterized by fixed dimensions and volumes, but they can be adjusted within stated guidelines to suit a wide variety of sites, configurations, and aesthetic treatments. After two decades of actual use, the VA has found the VAHBS to be very cost effective in facilitating introduction of new mechanical and electrical systems to support advancing medical technology.

A key element of VAHBS is the use of interstitial space (see Figure E-1), a 9-foot floor-between-floors that houses mechanical and electrical components. This space is constructed as a working floor, and seven vertical layers are reserved for various main, branch, and lateral distribution elements.

Figure E-2 illustrates how the interstitial space fits into the VAHBS one-story building module. The module is restricted by fire safety regulations to no larger than 22,500 square feet overall, but structural bays may vary from 24 to 27 feet wide, 41 to 59 feet deep, and 19 to 21 feet high. A service bay located on the narrow side of the module provides a vertical link to carry mechanical and electrical equipment, and shafts and stairs so that the modules

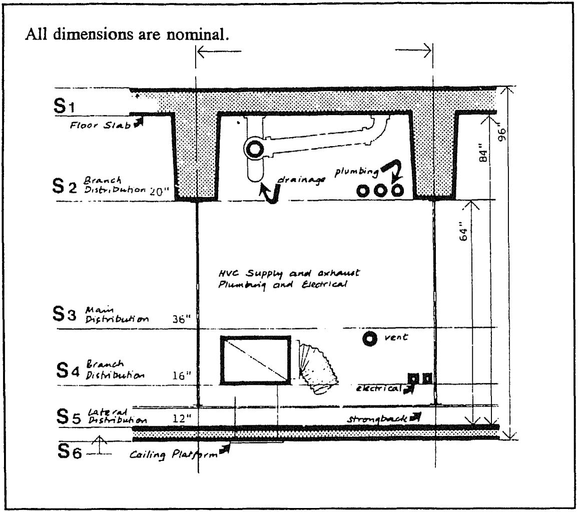

Figure E-1 VAHBS vertical zone organization within module (figure courtesy of Stone Marraccini Patterson [SMP]).

interstitial space in the VAHBS, which some designers feel is overly generous.

The Army Corps of Engineers also has had a satisfactory experience with its integrated building systems (IBS). The Corps' *Medical Design Standards* include guidance on evaluation and design of IBS hospital facilities. The IBS systems module is a unit one floor high, and is served by its own service distribution systems and utility pod, with a floor area of 10,000 to 22,500 square feet. Easy equipment accessibility to maximize facility life span is cited as one of the factors comprising the IBS design intent.

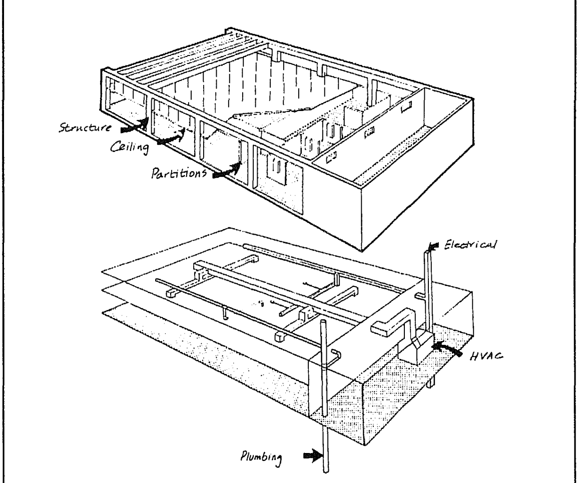

Figure E-2 VAHBS one-floor basic building module.

APPENDIX F
ANNOTATED BIBLIOGRAPHY

Prepared by Thomas Walton, Ph.D.

American City and County. 1987. St. Paul computerizes facilities maintenance. March:47.

A computer in St. Paul monitors maintenance needs; keeps track of costs, warranty, and liability issues; issues work orders; and centralizes building upkeep. The process also simplifies budget justifications.

Architectural Lighting. 1988. Retrofit cuts energy costs, preserves appearance. February.

Retrofitting the Transamerica Pyramid with specular silver reflectors has reduced maintenance and energy costs, including a reduction in the air conditioning load. The rehabilitation should pay for itself in 2 years.

Bilodeau, R. J. 1973. Technological innovation in Canada. Cost and Management. March–April:12–15.

Innovation, meaning bringing invention to market, is critical to a country's economic success. Witness the robust development in the United States. Canada must create a similar climate for innovation, and steps in that direction might include greater tax advantages for innovative industries, more generous capital cost allowances for high-tech firms, a more lavish use of stock options, the ability for small companies to carry forward losses for

Bosworth, D. L. 1978. The rate of obsolescence of technical knowledge—a note. The Journal of Industrial Economics XXVI, (3):273–279.

Based on patent renewal information in Great Britain, the author predicts that obsolescence of technical knowledge is more than 10 percent per year.

Buffalo Organization for Social and Technological Innovation. 1983. The Impact of Office Environment on Productivity and Quality of Working Life. Buffalo: BOSTI.

This is an analysis of the environmental and design factors that enhance the quality and productivity of offices. Estimates of the economic value of improved or lost productivity is an interesting feature of the study.

Building, 1985. Designing for change. July:46–47.

To enhance the flexibility of the new high-tech office, an adaptable distribution system is needed. Raised office floors (100 mm minimum) are an excellent choice to serve this need. They can streamline wire management, and they offer space for air distribution. Regarding the latter issue, because office equipment generates so much heat, air conditioning is the critical need. According to the author, cool air is delivered more economically and comfortably from floor rather than ceiling ducts since it will not mix prematurely with the rising air heated by the office equipment. To keep such a system in balance, floor ducts can be moved and an exterior heating system can be installed to respond to those perimeter areas that need heat rather than cooling. Lighting is another critical energy/heat concern in building design and user comfort.

Building. 1985. In touch with telecoms. July:44–45.

Telecommunications wiring and services are, in the postmonopoly era, becoming more complex. As well as the level and type of service, there are questions related to fire safety, control and flexibility, and the compatibility of equipment.

Building Design and Construction. 1986. Retrofit expands wire capability of

the following new design demands on these structures: space for cables; reliable, secure, and uninterruptable sources of power; unusual structural loads to support computers and antennas; a variety of different heating and cooling requirements; special lighting and acoustic problems; and, above all, flexibility.

To respond to these needs, designers should follow this process: (1) articulate clearly a building's mission and electronic performance requirements, (2) involve a multidisciplinary design team, (3) include a "commissioning" period as part of the construction schedule, (4) employ various diagnostic techniques as part of the construction and commissioning phases of the project, and (5) establish a permanent postoccupancy evaluation (POE) evaluation team as a facet of the building management structure. This team should include a facilities manager, an information technologies manager, and a personnel manager.

Building Research Board. 1989. Improving the Design Quality of Federal Buildings. Washington, D.C.: National Academy Press.

This is an investigation of the design, construction, and building management process, with specific suggestions and policy recommendations for improving quality. Five areas receive particular attention: (1) predesign planning and programming, (2) architect/engineer selection, (3) participation in design and construction, (4) design evaluation, and (5) building approval and general management.

Building Services. 1986. Tracing out the pipework. May:55.

Using trace heating devices, water can be maintained at a constant temperature without being recirculated. In this technology a heat-sensitive, energy-releasing tape is placed along the hot water system and keeps water temperatures at a certain minimum. Boilers can be smaller, pumps and return pipes are eliminated, and water is saved. Net savings depend on building use and installation costs.

Bumbary, R. C. 1989. The VA Hospital Building System: Building better hospitals for veterans. Unpublished paper, Department of Veterans Affairs, Office of Facilities. December.

April:28–35.

Hospital needs, design, and technology are changing so fast that avoiding obsolescence is a difficult challenge. In any building project several issues must be analyzed: construction sequence, safety, who the users are, technical needs, various building systems, handicapped access, and radiation shielding, as well as electrical, HVAC, and plumbing equipment. Factors that affect final decisions include cost, service requirements, and function.

Commercial Renovation 1988. Time and money favor retrofit. December:46–47.

In Phoenix it was cheaper and faster to renovate an old Safeway into an outpatient center than to build a new one. New sprinklers; facades; interiors; and mechanical, lighting, and electrical systems were added. In the end the savings came to more than $200,000, and the building was occupied 6 months before a new structure could have been completed.

Construction Industry Institute, Design Task Force. 1986. Evaluation of Design Effectiveness. Austin: University of Texas at Austin.

This shows the development of a matrix-based model for measuring design performance using accuracy, useability, cost, constructability, economy schedule, and ease of start-up as evaluation criteria.

Croome, D. 1990. The impact of technological innovation on the construction industry. The Journal of CIB 18(3):174-182.

Despite the fragmented nature of the construction industry, there is a genuine need to incorporate innovation. This requires a better education with more technical background and better testing of new systems, including their impact on users. The ultimate goal should be to improve performance, quality, and durability.

Information technologies are having an impact on construction in terms of computer-aided design (CAD), site automation, and new materials, but

considering their effect on human beings. This last aspect is critical. Designers must ask how new technology enhances communications, creativity, personal control, environmental quality, and basic human needs. Issues of pollution, maintenance, conservation, and decentralized control are important.

Cunningham, R. M., Jr. 1982. Design trick: Guessing right for a future that's anybody's guess. Hospitals. February 16:96–99.

This is a discussion of the difficulty in predicting future trends in hospital needs and design, with an analysis and a forecast of a few critical issues.

Doyle, M. 1985. Older buildings ripe for telecommunications retrofit. Building Design and Construction. June:66-68.

Many older buildings can be improved to better serve tenants by a telecommunications retrofit. The space needed for this effort often can be found in mechanical equipment areas, because older systems traditionally are oversized. Prior to making a commitment, owners should assess whether or not tenants can afford to subscribe to the new services. Small-and medium-size businesses are the most likely takers.

Doyle, M. 1986. Retrofitting for microelectronics research. Building Design and Construction. August:76–77.

This addresses the 1983 saga of how MIT's Microsystems Technology Laboratory (MTL)—a "clean" research center—was installed in an old data processing building. Among the many issues addressed are floor height, lighting, removable wall panels, vibration, and mechanical systems.

Federal Construction Council, Consulting Committee on Architecture and Architectural Engineering. 1990. The Use of Standard Designs for Federal Facilities. Washington, D.C.: National Academy Press.

This is composed of a series of articles on the use of standard designs in the federal and private sectors, including the VA, the U.S. Postal

Presentations and narrative cases address planning concerns in the government and corporate worlds. In addition to discussions of planning in the Air Force, the Navy, and along Pennsylvania Avenue in Washington, D.C., there is information on the role of computers, the dilemmas in hospital planning, and the potential for public-private partnerships.

Gautschi, T. F. 1982. OD & hi-tech series: Technological obsolescence—Part 2. Design News. May:141.

In the 1970s the half-life of an engineering education was estimated to be 10 years. Today, in some fields it is inevitably shorter. To address this obsolescence and simultaneously develop management skills—many of which are dependent on long-term experience, firms must develop strategies to keep re-educating the engineering and management staff. As one solution, some companies are separating expertise and promoting parallel career paths—one for engineers and another for managers. Others are giving engineers and managers time—perhaps 1 day a week—to study and keep up with new technologies. Still others are offering their engineers sabbaticals as an encouragement to stay current with scientific advances.

Government building finds comfort in retrofit. Consulting/Specifying Engineer. 1988, July, pp. 58–62.

At the State of Illinois Center, an innovative HVAC system, notably a major ice storage component, failed to keep the building cool in the summer and warm in the winter. Much of the problem was due to inaccurate assumptions about both equipment capacities and how the building would be used. An extensive renovation included a new chilled water plant, conversion of the ice-making system to a closed configuration, and installation of higher-capacity fans.

Greenberg, R. H., R. F. Sharp, and E. E. Spires. 1989. A practical method of measuring current costs of technologically inferior assets. Journal of Business Finance & Accounting 16(3):433–441.

Authors address the issue of how to measure the effects of technological change on current costs of plant assets. Present accounting rules require an

Groak, S. 1990. The decline of robust technologies in the building industry. The Journal of CIB 18(3). May/June:162–168.

Recent declines in the quality of buildings can be attributed to the de-skilling of the workforce, the failure of the educational system to provide adequate training, the absence of quality assurance, and inadequate testing. A growing uncertainty on the part of contractors in terms of workload and the type of skill required exacerbates the problem. There is also the fact that the contracting team is becoming more fragmented. This creates a turbulent environment; in addition, a changing technology reduces the repertoire of "robust" or proven technologies.

Hartman, T. 1989. Total involvement engineering. Heating/Piping/Air Conditioning. August:67–71.

The technological complexity of present building systems makes the traditional approach to design obsolete. Total involvement engineering (TIE) is a team alternative to the hierarchical/linear design process. The focus of the TIE team is having project and engineering input on an equal basis with the other design components, the client, the construction manager, and the contractor. The common goal of the group is to achieve the best building performance possible, and each member contributes toward that objective. Effective communication is one of the keys to success.

Other contributions are made by handling the design fees and procurement procedures differently. In the TIE approach the overall budget for design, construction, commissioning, and start up for each element of the project is established in advance, and funds can be shifted among these categories as long as the bottom line is not violated. TIE also encourages life-cycle additions to the budget, as long as they can be justified economically. With respect to procurement, evaluations are made in terms of both price and performance—a critical balance when dealing with high-tech systems. Specifications have to be written carefully, and contractors perhaps may be encouraged to submit two or three options for particular systems.

Finally, TIE needs to include postcompletion commissioning, start-up,

Terminal-regulated air volume (TRAV) HVAC technology unifies the fan and air supply points into a single system. Sensors determine if a room is occupied, and the output required at one vent is factored into needs at other distribution points. This unified approach reduces fan-speed requirements, generally avoids "air starvation," and distributes reductions in air supply across the system. A well-chosen control system is key to implementing the TRAV technology successfully.

Hayes, R. H., and R. Jaikumar. 1988. Manufacturing crisis: New technologies, obsolete organizations. Harvard Business Review. September-October:77–85.

New technologies require new approaches to management. Contemporary managers should devote their time not to controlling individual elements of a business but to making the pieces fit together. Sometimes the related aspects of different systems cause a conflict of interest (e.g., reducing inventories may require going to more expensive and reliable suppliers; thus, the materials manager's gain is the purchasing manager's loss). In this environment generalists are essential, and the overall view—the total of all the parts—is more important than an analysis of any individual part. The stress is on horizontal relationships rather than vertical hierarchies—on enhancing organizational capabilities rather than measuring and controlling costs.

Health Facilities Research Program. 1988. Hospitals as Intelligent Buildings. American Institute of Architects/Associated Collegiate School of Architecture Council on Architectural Research, Washington, D.C.

This is composed of series of presentations on the definition of "intelligent buildings" and the implications of that on building automation, telecommunications systems, and hospital design.

Jackson, D. W. 1976. Is planned obsolescence obsolete? Arizona Business. November:11–17.

Obsolescence can be measured in many ways: physical, technological, and psychological. Interestingly, there are both positive and negative

information to evaluate alternatives, and a choice with respect to durability.

From the seller's perspective, planned obsolescence may be useful for goods that are used infrequently or are unidentifiable by brand. In other situations, however, it may be a negative factor, limiting repeat business and profits. With respect to technological obsolescence, a manufacturer may withhold advances, but this may give competitors time to catch up, so that strategy is not always economically successful. Nor is psychological obsolescence—style changes—always financially rewarding. It takes money to develop consumer awareness, and buyers may resist superficial change.

From a societal vantage point, obsolescence encourages innovation, and full employment, it offers consumers product options, and it supports a market for used equipment. On the other hand, planned obsolescence can waste resources and lead to the withholding of advances from the marketplace.

Kelsey, D. and D. R. Webb. 1990. Moving into digital control through retrofitting. ASHRAE Journal 32 (7): 12, 14–16.

Direct digital control (DDC) can be integrated more easily with existing HVAC control systems. Such a retrofit can improve temperature accuracy and comfort, reduce maintenance, provide better environmental monitoring, enhance a building's value, and save energy dollars. The interfaces among various components of the HVAC system and DDC are the most critical design issues in any retrofit.

King, J. and R. E. Johnson. 1983. Silk Purses from old plants. Harvard Business Review. March-April:147–156.

Renovating older industrial buildings can save money on site acquisition, infrastructure development, transportation and construction. This conclusion is based on a study of Michigan factories, some of which were renovated for as little as one tenth the cost of new construction.

Some of the drawbacks of factory reuse are poor column spacing, low floor-to-ceiling height, constricted configurations, inefficient exteriors, inadequate vertical circulation, and congested sites.

This examines the definition and refinement of a life expectancy of a facilities model based on a weighted average of the six principal building components: mechanical, foundation, electrical, structural frame, exterior walls, and plumbing.

Knott, A. W. 1988. Quality vs litigation in the design and construction industries. Forensic Engineering 1(3):123–130.

Changing the way disciplines relate in the construction industry can improve quality of construction and reduce litigation involved. In the traditional American approach decisions are made with a "management by objectives" technique. In the Japanese system responsibility is shared, and all the players are involved in gathering data and making management decisions. If the United States is to learn from the Japanese example, contractors need to define objectives in terms of quality, make sure those standards are the as the owner's, define how those objectives will be measured, ask all employees to participate in taking appropriate measurements and comparing them with the ideal, and coordinate suggested improvements in the construction process to meet the original standards.

Leov, G. and G. Mangurian. 1984. Alternatives to replacing obsolete systems. Journal of Information Systems Management. Fall:89–93.

Replacing obsolete information systems is not automatically the best approach. As an alternative, decision-makers should analyze the existing system's technical condition and functional adequacy and then list deficiencies. Next, several approaches to resolving these deficiencies should be evaluated: maintenance, renovation, augmentation, replacement, and elimination. Each of these options should be priced and studied in terms of its cost/benefit ratio. Only then can a decision be made.

Lockwood Greene Engineers. 1989. Retrofitting brings new life to existing buildings. Consulting/Specifying Engineer. August:42–53.

Buildings are machines serving particular functions, from industrial

save both time and money over new construction. On the other hand, it may not be economically viable to retrofit structures more than 30 years old.

Retrofit projects require sound management practices, such as those that follow, to keep costs under control: have accurate documents and phase work to minimize disruptions; assume that higher cost estimates are the more accurate, especially on complex projects; before making a final commitment, assess a building's structure, available utilities, skin, mechanical systems, and access; and determine the level of upgrade required and any special programmatic needs.

This includes a discussion of electrical system, computer, energy, HVAC, lighting, and security needs. Checklist included in boxes.

Loring, J. R., J. O. Samuel, and I. Zupovitz, P.E. 1988. Retrofitting commercial buildings—opportunities and problems. Consulting/Specifying Engineer. July:46–53.

The retrofitting of buildings falls into several categories: adaptive reuse, total retrofit, progressive retrofit, and progressive but periodic retrofit. Among the components of such a retrofit are electrical and communications systems, HVAC, life-safety systems, individual environmental controls, lighting, security, and elevators. The constraints on renovation are schedule, budget, floor-to-floor heights, access, and asbestos removal. The motivation to renovate includes reducing operating costs, reclaiming space, and upgrading equipment. A general evaluation of alternatives can be made by building age: pre-1950s offices, offices constructed in the 1950s and 1960s, and those completed in the 1970s and 1980s.

To illustrate different mechanical systems options, the authors describe the retrofit of the Boston Federal Reserve Bank, the National Academy of Sciences Offices in Georgetown, the National Education Association Headquarters in Washington, and a 40-story office at an undisclosed location. The conclusion of this analysis is that the older the building, the easier the retrofit, and that the economic incentives to renovate depend on the cost of energy, who pays for operating costs, and the investment potential of the structure.

Masters, L. W. Prediction of service life of building materials and components.

need for more accurate service-life prediction. There are, however, technical barriers to reliable short-term service-life tests, and the author suggests both how these might be overcome and an agenda for future research.

Masters, L. W., ed. 1985. Problems in Service Life Prediction of Building and Construction Materials. Boston: Matinus Nijhoff Publishers.

Focusing on inorganic, polymeric, and metallic materials, this volume contains more than a dozen essays and reports on these themes: state of the art of service-life prediction of building and construction materials, approaches to service-life prediction in advanced technologies, commonalities between service- life prediction problems in building/construction technology and advanced technology, mathematical analysis techniques used in advanced technologies, mathematical analysis techniques used in building and construction technology, and recommendations.

Newman, J. H. 1978. Commercial buildings: Retrofit and other energy opportunities and strategies. Journal of Property Management. November-December:325–332.

Because existing commercial structures represent such a large portion of building stock, energy retrofits are critical to achieving significant savings. Achieving this, however, requires that more and better information is needed since most owners are unaware of their building's energy use. Such a study was done for 250 million square feet of office space in New York City from 1971 to 1975, and many energy consumption details were revealed.

One of the conclusions was that older buildings generally consume less energy per square foot than new ones. Another was that the larger and newer—but not the newest—buildings are the most effective targets in terms of conservation. Controlling ventilation and turning off lights in unoccupied spaces are simple examples of potential areas for savings. The point is to have information in order to know how to make the most effective energy-efficient decisions.

a variety of job assignments, and the opportunity for promotion reduce obsolescence, as does participation in decision-making.

Pan Am Building retrofitted for efficiency. 1986. Building Design and Construction. March:94.

The addition of a computer to monitor mechanical systems improves efficiency and comfort as well as enables facility managers to better cope with emergencies.

Parker, W. Jr. 1979. Flexible designs are key to reuse projects. Hospitals. February 16:125–126.

The author proposes a planning/program/design model that makes the testing and developing of reuse/reconfiguration proposals in hospitals potentially more successful both functionally and economically.

Pierce, C. F. Jr. 1979. Hospitals' future depends upon long-range planning. Hospitals. January:80–86.

All hospitals should have an ongoing planning process. This is especially important as government takes a more active role in health care. Such planning should consider both internal and external environmental factors when developing proposals and policies. It may be necessary to call on outside expertise to devise effective strategies and to form associations with other institutions as a way of sharing information.

Pilzer, P. Z. 1989. The real estate business and technological obsolescence. Real Estate Review 19:30–33.

Real estate has three main functions: (1) assisting tenants to distribute goods and services; (2) assisting tenants to create, market, or stimulate ideas and to process information about their products; and (3) providing tenants with machines for living. Technology is changing dramatically the profile of these operations and simultaneously is rendering much commercial real estate obsolete.

In the retail area, advertising and marketing have shifted loyalty from

manufacturing and ordering times will reduce the need for warehouses. Statistically, 80 to 90 percent of the cost of retail merchandise is in distribution. Therefore, the real innovations in retailing will be in distribution—not manufacturing.

Similar transformations will occur in office design, where the focus will be on helping customers process information.

Raftery, J. 1988. Dynamic rehabilitation. RIBA Journal. August:61-77.

Building obsolescence occurs when the cost of providing the benefit of a structure exceeds the value of the benefit obtained. Under this definition, recent as well as older structures can be obsolete. For example, the 10-year-old Toxteth estate is being razed because it seemed impossible to rehabilitate the units to anyone's satisfaction. The challenge with rehabilitation is to find the best possible return for the rehabilitation investment. Designers must be sensitive to modern service needs, high costs, structural and space constraints, and the historic character of rehabilitated buildings. Social and political benefits also need to be part of the rehabilitation equation.

Research Staff, Office of Construction, Veterans Administration. 1968. Feasibility Study—VA Hospital Building System. Washington, D.C.: Government Printing Office.

This is a detailed review of a system of building components designed to provide better hospital design at a lower cost. The first volume outlines the system, and its dimensions, elements, implications for design, and construction and procedures for implementation. The second volume discusses the parameters that affect the feasibility of the system, including form, function, and technical issues. The third volume is a compendium of sample studies and specifications.

Schmenner, R. W. 1983. Every factory has a life cycle. Harvard Business Review. March-April:121–128.

Even more so than declining sales (27 percent) and high labor costs (21

employment. A third way to avoid obsolescence is to identify and plan ahead for the life cycle of the plant. Such a plan should address the start-up years, the mature years, and the failing years of a facility's history and should cover such topics as plant engineering, work force, overhead functions, control systems, and contingency issues.

Sequerth, J. and T. DeFranks. 1987. Intelligent features upgrade facilities. American City and County. March:42,45–48.

Intelligent buildings are those that use sophisticated electronic controls to deal with environmental, security, safety, communications, and elevator issues. They respond to human needs and save money for owners. In Seattle an environmental control system improved comfort and reduced energy use by 20 percent. VAV have been used in a Phoenix municipal building to cut energy costs by $2000/month. The authors include many other anecdotes to illustrate their points, including some about computer interfacing and security options.

Souhrada, L. 1990. A-1 renovation: Planning for the future. Hospitals. February:58–60.

This presents the argument to develop multiyear plans to address new hospital needs rather than to deal with them piecemeal. Boxes call out some special problems, trends, and statistics.

Sraeel, H. 1988. Retrofitting power distribution: Keeping pace with technology. Buildings. November:64–66.

It is valuable to know who the clients will be in an electrical retrofit since different types of work have different needs. Next, owners must take a survey of existing capacity and the willingness of the utility company to provide additional service. At this point, the method and location of distribution need to be determined, as well as who will pay for tapping into the new lines. Costs range from $3 to 5 per square foot. In terms of horizontal distribution, alternative designs include power poles, poke-throughs, and flat cable. Most retrofits, however, are done as overhead installations. Vertical distribution can occur in abandoned elevator

of information in a hospital setting. Ideally, this should be a system that supports operational and decision-making processes. Flexibility for collecting and manipulating databases, the integration of educational programs, and a user-friendly interface are qualities to seek out and to plan for. Such a holistic approach requires long-term planning.

Tye, R. P. 1979. Retrofit thermal insulation: An evaluation of materials for energy conservation. Technology and Conservation (3):36–42.

The energy crisis mandates the need for more effective insulation. Many structures require a retrofit. This article discusses where and how to insulate and evaluates alternative insulation materials.

Walton, T. 1988. Architecture and the Corporation: The Creative Intersection. New York.

This is an analysis of how facilities are assets that can be actively exploited to enhance the corporate bottom line. The book includes several detailed case studies and an outline of a decision-making process owners can use to take advantage of this resource.

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shape and accomplish the strategic and operational objectives of an organization. Observers of the U.S. construction industry have expressed concern that failure to manage technology effectively—at the level of the nation and the individual firm—is a primary factor underlying a perceived risk that U.S. industry is losing its competitive edge in an increasingly global marketplace. These observers argue that action is needed to deal with issues such as liability and societal risk aversion, short-term perspectives, and traditions that divert resources and discourage innovation in both the processes of construction and in facilities. The Building Research Board has undertaken, through this strategic program, to focus discussion and stimulate appropriate response to such issues.

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